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THE SKULL OF SINANTHROPUS PEKINENSIS;

A COMPARATIVE STUDY ON A PRIMITIVE HOMINID SKULL

BY

FRANZ WEIDENREICH

WITH TABLES I-XXXVIII AND PLATES I-XCIII

古生物誌
地質調查所

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I THANKFULLY DEDICATE THIS STUDY TO

DR. WANG WEN-HAO

Former Director of the Cenozoic Research Laboratory,
Minister of Economic Affairs

AND TO MY COLLABORATORS

PÈRE TEILHARD DE CHARDIN
DR. YOUNG CHUNG-CHIEN
DR. PEI WEN-CHUNG
MR. M. N. BIEN

whose unresting efforts brought full success
to the excavations in Choukoutien,
until the Japanese invasion barred all activity
and made uninhabitable our field headquarter erected there
to facilitate our work devoted only to science

FRANZ WEIDENREICH

PREFACE

Of all the *Sinanthropus* material recovered from Choukoutien during the last decade only the skulls remained to be described. This was not done so long as there was hope that new finds might complete the series. The turn taken by political events in the Far East has frustrated all those expectations, and since no one can foresee whether or when it will be possible to resume our work in Choukoutien it seems advisable not to delay publication on the material at hand.

Being apprehensive of what lay ahead, all the skull material had been photographed, drawn and measured, and casts had been made which were shipped to this country. Thus, research could be continued even when we were forced to liquidate the Cenozoic Research Laboratory and to leave Peiping. When that time came, I found myself received by the American Museum of Natural History in New York, thanks to the kind invitation of Dr. William K. Gregory, Curator of Comparative Anatomy, and the administration of that museum, and was able to finish the work so regrettably interrupted.

There were, however, some difficulties. Dr. R. von Koenigswald, with the financial support of the Cenozoic Research Laboratory, had made new and surprising discoveries on Java's already famous soil—discoveries which may lead to a fundamental revision of our conceptions, so far as the *Pithecanthropus* type and its relation to *Sinanthropus* are concerned. What direction the eventual corrections may take is alluded to in this paper. But it would have been a greater help, had I had the chance to widen the basis of this study by more precise references to these strange types of Java man. Unfortunately, the war and the consequent interruption of all communication with Java has made this impossible. Fortunately, the data referring to the *Pithecanthropus* Skulls II, III and IV—so far as the latter is of use in its present stage of preparation—were available although Dr. von Koenigswald's description of his material is still unpublished. I was further handicapped by the lack of publication on the *Homo soloensis* skulls. Except for an announcement of their discovery by Dr. W. F. F. Oppenoorth and a later, supplementary article by the same author, they remain completely unknown to the scientific world, despite their extraordinary significance for our knowledge of Early Man, in general, and that of Early Man of East Asia, in particular. Thanks to the kindness of Professor W. A. Mijsberg in Batavia, I had brief access to the originals, and thanks to the liberality of Ir. W. C. B. Koolhoven, Director of the Geological Survey of the Netherlands Indies in Bandoeng, I had the opportunity to study the entire material as casts—a study which enabled me to assign the Ngandong skulls to their proper place in the evolutionary line. Therefore, to check the data on which I have relied with the originals is a future task.

This paper is divided into three parts. The first deals with the material itself. The second contains all the morphological data on the individual skulls and skull fragments with an analytic summary at the end. In the third part all groups of hominids have been submitted to renewed scrutiny on the basis of the facts revealed by the *Sinanthropus* skulls, and here a summary showing the results of this comparative review closes the paper. However, some repetition was inevitable: In order that the reader might form a judgment of the characters described, the second part also contains many references to the special appearance of the features discussed both in other hominids and in the anthropoids.

The photographs of original material used in this paper were executed in the Photographic Bureau of the Peiping Union Medical College. The drawings of the originals were made, partly by the artist of that College, Mr. Chiang Han-cheng, and partly by the artist of the Cenozoic Research Laboratory, Mr. Chen Chih-nung. The casts of the *Sinanthropus* material were made in the Cenozoic Research Laboratory in Peiping by Mr. Hu Ch'en-chih as were those of *Pithecanthropus* material which was prepared in that place. I wish to thank each of them for the great skill and understanding with which they have performed their difficult tasks. Most of the craniograms and diagrams were made by Miss D. F. Levett Bradley, working at the American Museum of Natural History.

The actual writing of this paper, as I have indicated, was done at the American Museum of Natural History in New York. Again I wish to thank that museum for its hospitality and especially to express my thanks to Dr. William King Gregory, Dr. Harry Shapiro and Dr. Edwin H. Colbert of the museum staff all of whom have aided my work. In the matter of technical transcription I must thank the former Secretary of the Cenozoic Research Laboratory, Mrs. O. H. Gown, in Amesbury, Mass. who lent her help in preparing a great part of this paper for publication while Miss Jannette M. Lucas revised much of the manuscript.

I wish furthermore to thank Mr. Edwin C. Lobenstine, Chairman of the China Medical Board, Inc., Mr. Warren Weaver and Mr. Frank B. Hanson of the Division of Natural Sciences of the Rockefeller Foundation who consented to have this paper printed and edited in the United States as a monograph of the PALAEONTOLOGIA SINICA where my main reports on the *Sinanthropus* material have previously appeared. Miss Agnes M. Pearce, Secretary of the China Medical Board, kindly took many of the troubles arising from this arrangement upon herself.

FRANZ WEIDENREICH

New York 24
American Museum of Natural History
June 7, 1943

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I. SINANTHROPUS
A. Calvariae

INTRODUCTION

In my earlier contributions to the study of Early Man I pointed out repeatedly the danger of confusing anthropological facts with geological facts. In determining the character of a given fossil form and its special place in the line of human evolution, only its morphological features should be made the basis of decision; neither the location of the site where it was recovered nor the geological nature of the layer in which it was imbedded are important. Discrepencies cannot be smoothed out by bringing morphological facts and opposing geological data into closer harmony with artful interpretations or by touching-up reconstructions. It is a generally accepted conception that Man has developed in the course of time by gradual transformation from an ape-like type to the type he presents today. Viewed from this fundamental standpoint, it is logical to assume that the more a form resembles the supposed ancestor the more ancient it will be, or that the more ancient it is the more "primitive" it should be.

There is no doubt that some discoveries of recent years do not seem to fit well into such a scheme. The fragments of the calvaria of Piltdown cannot be distinguished from those of modern man, either in their general form or in individual features. Yet, if the geological evidence that the site belongs to the Interglacial Günz-Mindel Phase of the Pleistocene is incontestable, the fragment would constitute the earliest human remains ever found anywhere—much more ancient than *Sinanthropus* or *Pithecanthropus*, which, despite their more primitive morphological appearance, belong to the same geological phase as Piltdown or to an even more recent one.

The Swanscombe and Steinheim skulls present similar difficulties. The horizon from which the Swanscombe skull was recovered is attributed to the Interglacial Mindel-Riss Phase, but there is no feature in the bones, as they are preserved, that might not be found in any racial group of modern man.

The case of the Steinheim skull is a little different. It belongs to the Interglacial Riss-Würm Phase or perhaps to a somewhat older one, but it differs characteristically from modern man, particularly in the face, the general form of the braincase, and the frontal bone. Nevertheless, the skull deviates fundamentally less from the modern type than does the classic Neanderthal Man of Europe, despite the fact that the latter—pertaining to the Würm I Phase—is geologically younger.

The differences in time become still more striking when calculated in years by Zeuner's (1940) chronologization, in which case the type of modern human braincase would have been developed in England about 500,000 years ago, although no vestige of a more primitive type has ever been found there. In France and Germany, however, there existed a much more primitive type, only 115,000 years ago, than that living in the much older period in England, although no vestige of a more advanced type has ever been discovered in the preceding geological periods of these countries.

The problem cannot be solved by calling an apparently anachronistic type like the Steinheim Skull "pre-Neanderthaloid," as did Weinert (1936.) The Steinheim Skull is "pre-Neanderthaloid" only when classified according to its geological character but certainly not according to its morphology. After all, our knowledge of Early Man is still very fragmentary. Despite the great progress made in the last few decades, our discoveries are minimal when space and

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time are taken into account. Correct classification of the various types will be possible only when a much greater number is known. But I cannot believe, even making very liberal allowance for these uncertainties, that such incongruity between morphology and chronology as is found in the case of Piltdown can be completely brought into accord. The only hope of solution in this case would lie in assuming that the human bones were not contemporaneous with the layer in which they were found but were deposited there later. Otherwise, modern man must be much more ancient than we ever imagined, or else Western European man did not pass through evolutionary stages as did the humans of other regions of the earth.

The latter possibility has thus far not been suggested in actual words but it has been intimated now and then in suggestions to the effect that man has developed, not by a steady process of transformation but in sudden spurts. However, it is now possible to prove that every peculiarity specific of modern man can be traced back, step by step, not to a definite anthropoid of today but to a form which has been at least close to it. Formerly, the existing skull material of Early Man was not sufficient, either in quality or quantity, to make such comparison fruitful, for the stages represented by this material were still very close to that of modern man and too far away from the initial ones. This situation changed fundamentally with the discovery of *Sinanthropus* and the new finds of *Pithecanthropus*. Neither form is at the very base of the human stem, but they are certainly nearer to it than all other known forms and can, therefore, be regarded with much more justification as the most "primitive" types known.

In using the word "primitive" to express the character of features with regard to their phylogenetic development, it must be borne in mind that "primitive" does not necessarily mean that those features originated in anthropoids. They may be "primitive" for hominids but absent in anthropoids. When G. Schwalbe (1901, 1907) studied the cerebral relief of the human parietal bone, he came across a structure that had heretofore escaped attention. In a certain percentage of cases he found the sphenoid angle occupied by a high crest that could only be the continuation of the edge of the lesser wing of the sphenoid fading out toward the center of the parietal bone. Schwalbe named this crest "crista sylvii." Since he found it completely absent in anthropoids and in all the catarrhines he concluded that the structure must be a progressive human character. Sir Arthur Keith, on the other hand, came to the opposite conclusion. While studying the Piltdown fragments anew (1938–39), apparently unaware of Schwalbe's description, he re-discovered the Sylvian crest of modern man. But since he found the crest completely absent in the Piltdown bone as well as in gorilla and chimpanzee, he declared the absence of the "Sylvian falx," as he named the formation, to be "the most striking anthropoid feature" of the Piltdown calvaria. Had Schwalbe and Keith used the term "primitive" in describing this peculiarity, they would have called the absence of the crest a "primitive," meaning an "anthropoid," characteristic. Actually, this is not the case. The Sylvian crest is a very specific feature in all the *Sinanthropus* specimens; it far exceeds in strength and extension anything of the kind that has been observed in modern man. The crest is also present in *Pithecanthropus* and in some of the Neanderthalians. Apparently, it represents a part of the reinforcement-system of the calvaria of Early Man that has undergone a gradual reduction during human evolution. The reinforcement-system as well as the crest is absent in gorilla and chimpanzee, which in this respect resemble modern man but not Early Man. There is reason to suppose that the structure once belonged to a common ancestral form, but was lost by its descendants, first by the anthropoids, later by man. "Ape-like" or "anthropoid" is, in this case, not identical with "primitive." The absence of the Sylvian falx in the Piltdown

parietal bone does not prove its "primitiveness," as claimed by Keith; on the contrary, it indicates its modern character.

Another excellent example to which I called attention in my paper on the *Sinanthropus* dentition (1937b) is that of the lower canine. The lower canine of modern man is more or less cuspidate, resembling very remotely the anthropoid canine. In *Sinanthropus*, however, the crown of the lower canine, in sharp contrast to the upper one, ends in a broad edge and looks more like an incisor than an anthropoid canine. In the Neanderthalians the distal half of the edge is bevelled while the mesial half retains its original character. In modern man the bevelling has extended to the mesial half as well. The pointing of the crown is, therefore, a late acquisition of man and not at all a "primitive" feature, as was formerly supposed.

Therefore, when the word "primitive" is used in this paper it should be understood to mean only "closer to the original form of man," irrespective of man's relationship to other primate forms. -

There can no longer be any doubt of the fact that modern man has passed through a series of succeeding stages, partly represented by what we call Pre-hominids, Neanderthalians, and the like. All these forms fit into one general pattern of evolution with respect to their shape as well as to their individual features. Therefore, if the Piltdown calvaria, for example, with its recent human character really belongs to the low Pleistocene, it must be assumed that there existed in the Tertiary somewhere in the Old World an ancestral type possessing the same morphological characteristics as *Sinanthropus* and *Pithecanthropus*. The one-toed *Equus* had a three- and four-toed ancestor, regardless of the region of the earth in which *Equus* may be found and the geological horizon from which it may be exhumed. Palaeontology has proved that there is no exception to this rule.

PART I

THE MATERIAL

In the following pages *Sinanthropus* Skull E described by Davidson Black (1931) will be referred to only in so far as necessary for completing our knowledge of the type. Skull D, however, of which not more than the measurements and craniograms contained in Black's paper are known will be included in the description.

A. Discovery of the Skulls and Skull Fragments and Their Designation .

Already in 1928, the second year of the excavation of Locality 1 of Choukoutien, Birger Bohlin, then in charge of the field work of the Cenozoic Research Laboratory, recovered parts of a badly damaged human skull cap. Some of the fragments were still *in situ*, others were almost unrecognizable pieces. Thanks to Davidson Black's extreme carefulness, it was possible to preserve the pieces *in situ* and to identify them as a parietal bone, and as fragments of a frontal bone (cf. Skull I in Table I). However, their crushed condition is such that only little could be gained from a study of the fragments augmenting the knowledge of the *Sinanthropus* skull. Shortly afterwards, W. C. Pei found a well preserved cranium at the site known as Locus E, which provided Davidson Black the opportunity to determine definitely the main characteristics of the skull. At approximately the same time bones of a second cranium were discovered embedded within the travertine blocks excavated at the site of Locus D and brought to the Laboratory in Peking for final preparation. In the following four years only two cranial bones were collected apparently because of the dearth of layers explored during this period. In 1936, when the excavation of Locality 1 reached deeper layers (Level 22), a relatively large number of cranial bones came to light. From Level 22 five skull fragments were recovered which probably belong to two individuals, and from Level 23 two fragments of two additional individuals. In the same year, Level 25 yielded three crania of adult individuals—Skulls I, II and III of Locus L—including parts of the facial skeleton of Skulls I and II. Finally, in 1937, just a few days before the Japanese-Chinese war broke out which disrupted our work in Choukoutien completely, the fragment of a maxilla was found at Level 29.

Table I contains all finds of cranial and facial bones recovered from Locality 1 listed in their respective current numbers. Each number represents a skull, regardless of the number or size of the pieces. In cases where several isolated cranial bones or fragments thereof had been derived from the same level and where substantiated proof existed of their belonging to one and the same skull, one number only is used in the following description for a general designation of the skull. It may be true that this procedure will produce some confusion in those cases in which the new designation contrasts that applied by Davidson Black and by the present author in earlier publications. Black referred to the sites where human material had been unearthed as "Loci," defining them in alphabetical order and the skull according to its Locus as "Locus D" or "Locus E" skull. In the progress of the excavations, however, it was found to be more convenient to designate the entire horizons as "Levels" and to distinguish the levels in arithmetical order. But since Black's original method of designation remained in use, it happened that, if several skulls were recovered from the same horizon, such being the case in Locus L, an additional designation became necessary as for example: Skull I Locus L, Skull II Locus L, etc.

TABLE I

Catalogue of Calvaria Recovered from Locality 1 of Choukoutien

A. Calvaria and Fragments

No.	Number of Fragments	Type of Specimen	Sex	Age	Site and Year of Discovery	No. of General Catalogue	Individual	Described in Earlier Publications	Illustrated in Figures:
I	2 larger and numerous small ones	1. Right (?) parietal bone (crushed) 2. Fragment of left half of frontal bone	M	ad.	Locus B: 39.2, 1928 (B. Bohlin and W. C. Pei)	PA 21 PA 78	B II?	Davidson Black—Bull. Geol. Soc. China, vol. 8, 1929, pp. 15–32	1–4
II	1	Calva (both temporals and occipitals missing)	?	ad.	Locus D (Lower Fissure), 1929	PA 17	D I	Described as Skull of Locus D by D. Black—Pal. Sin., Ser. D, vol. VII, fasc. II, 1931.	5–16
III	1	Calvaria	M	juv.	Locus E (Lower Fissure; Dec. 2, 1919), W. C. Pei	PA 16	E I	Described as Skull of Locus E by D. Black—Pal. Sin., Ser. D., vol. VII, fasc. II, 1931.	101–104
IV	1	Fragment of a right parietal bone	M	juv. or adol.	Locus G: Quartz Horizon 2—Kotzetang Cave, 1931, W. C. Pei	PA 23	G II	Mentioned by W. C. Pei—Bull. Geol. Soc. China, vol. 11, 1931, pp. 109–146.	17–20
V	2	1. Left temporal bone with adjacent parts 2. Fragment of a right temporal bone; tympanic region	M M	ad. ad.	Locus H; June 14, 1934 Locus H, 34: 27: 13; 1936	PA 74 Pa 86	H III	Described as Skull III by F. Weidenreich—Bull. Geol. Soc. China, vol. 14, 1935 and vol. 16, 1936/37.	21–27, 85, 105B, 28–30
VI	4	1. Fragment of frontal bone 2. Fragment of left parietal bone 3. Smaller fragment of the same parietal bone 4. Fragment of right temporal bone	F F F F	ad. ad. ad. ad.	Locus I, Level 22 (Layer 8) 36: 87, L-2; 1936 Locus I, Level 22 (Layer 8) 36: 85, F3; 1936. L. P. Chia Locus I, Level 22 (Layer 8) 36: 88, F3; 1936. L. P. Chia Locus I, Level 22 (Layer 8) 36: 87, L-2; 1936. L. P. Chia	PA 92 PA 90 PA 91 PA 93	I I	Described as Skull VI by F. Weidenreich—Bull. Geol. Soc. China, vol. 16, 1936/37.	31, 34 32, 35 33, 36, 105A
VII	1	Angulus mastoideus of right parietal bone	M	adol.	Locus I, Level 22 36: 81, B-4; 1936. F. Weidenreich	PA 326	I II	Described in F. Weidenreich "The torus occipitalis," etc. Bull. Geol. Soc. China, vol. 19, 1940.	37–40
VIII	1	Fragment of occipital bone	F?	juv.; not older than 3 yrs.	Locus J, Level 23 36: 95, B-3; 1936. F. Weidenreich	PA 95	J I	Described in the same place as No. VII.	41–45

TABLE I—*Continued*

No.	Number of Frag-ments	Type of Specimen	Sex	Age	Site and Year of Discovery	No. of General Catalogue	Individual	Described in Earlier Publications	Illustrated in Figures:
IX	5	1. Fragment of frontal bone 2. 4 small frag-ments without connection	M	juv. c. 6 yrs.	Locus J, Level 23 36: 95, L-3; 1936.	PA 315	J IV?		46–48
X	1	Calvaria (right temporal bone missing) (For facial bones belonging to the Calvaria see below under B I and II)	M	ad.	Locus L, Level 25 36: 155, J-3; Nov. 15, 1936. L. P. Chia	PA 98	L I	Described as Skull I Locus L by F. Wei-denreich. "Nature" vol. 139, No. 3511, pp. 269–272.	49–60, 106–108
XI	1	Calvaria (For facial bones belonging to the Calvaria see below under B III and IV)	F	ad.	Locus L, Level 25 36: 155, J-3; Nov. 15, 1936. L. P. Chia	PA 99	L II	Ibid.—described as Skull II Locus L	61–72, 109–110
XII	1	Calvaria	M	ad.	Locus L, Level 25 36: 166, I-2; Nov. 26, 1936. L. P. Chia	PA 100	L III	Ibid.—described as Skull III Locus L	111–112, 73–84; 90–100
XIII	1	Calvarium XIII represented only by left maxilla with six teeth (see be-low under B V)	M?	ad.	Locus O, Level 29 37: 186; 1937. L. P. Chia	PA 313	O I	See below under B V.	142–147
XIV	1	Calvarium XIV represented only by fragment of left maxilla with four teeth (see below under B VI)	M	ad.	Upper Cave, 33:32, D-4; 1933. W. C. Pei	PA 115	UC ?		153–156

B. Separate Facial Bones

No.	Number of Frag-ments	Type of Specimen	Sex	Age	Site and Year of Discovery	No. of General Catalogue	Individual	Described in Earlier Publications	Illustrated in Figures:
I	1	Frontal process of left maxilla	M	ad.	Locus L; 1936 (see above under A X)	PA 98	Belongs to Skull X (see above under A X)		135, 136
II	1	Fragment of left zygomatic bone	M	ad.	Locus L; 1936 (see above under A X)	PA 98	Belongs to Skull X (see above under A X)		160–163
III	1	Fragment of left maxilla with five teeth (P^1–M^3)	F	ad.	Locus L; 1936 (see above under A XI)	PA 99	Belongs to Skull XI (see above under A XI)	F. Weidenreich: The *Sinanthropus* denti-tion; Pal. Sin., N. S. D, No. 1, Whole S. No. 101, 1937.	148–152

TABLE I—*Continued*

No.	Number of Fragments	Type of Specimen	Sex	Age	Site and Year of Discovery	No. of General Catalogue	Individual	Described in Earlier Publications	Illustrated in Figures:
IV	1	Approximately right half of palate	F	ad.	Locus L; 1936 (see above under A XI)	PA 98/99	Probably belongs to Skull XI (see above) under A XI)		157–159
V	1	Fragment of left maxilla with six teeth (I², P¹–M²)	M?	ad.	Locus O; 1937 (see above under A XIII)	PA 313	O I Skull XIII	F. Weidenreich: The *Sinanthropus* dentition; Ibid.	142–147
VI	1	Fragment of left maxilla with four teeth (P¹, M¹–M²)	M	ad.	Upper Cave; 1933 (see above under A XIV)	PA 115	? Skull XIV (see above under A XIV)		153–156

Thus, I have decided to abandon that entire system by listing the skulls under their current numbers only. In order to facilitate the identification of the skulls described earlier under different designations, a special column in Table I lists their original definition.

In my paper on the *Sinanthropus* population (1935) I made the attempt to establish the number of individuals to whom the various skeletal parts derived from the same level could reasonaly be attributed. These bear their identification according to Locus as well as special numbers designating the respective individuals. The column in Table I under the heading "Individual" indicates the one to which the skull belongs, while a comparison with the catalogues given in previous publications on the *Sinanthropus* material will reveal what other skeletal parts or teeth may be ascribed to the same individual.

B. State of Preservation of the Material

As is evident from the catalogue, none of the 14 skulls recognized as belonging to *Sinanthropus* is complete. Not less than five of these are represented by fragments of a single cranial or facial bone, four by more than one isolated piece and five are calvariae with or without basal parts preserved. All of the *Sinanthropus* material recovered from Locality 1 is characterized by its fragmentary condition. Their poor state of preservation cannot be attributed to secondary destructive agents but rather to the original condition of the finds or, in other words, the bones underwent mineralization in their entirety just as they were. I shall refer to this question in a later chapter.

Skull I (Figs. 1–4)

Skull I consists of two recognizable larger fragments and numerous small ones which apparently belong to the same cranium but are so broken as to render their identification as well as a restoration of the skull cap impossible. All of the pieces were recovered from the same site (Locus B) in 1928.

The main fragment (No. I, 1) is a parietal bone (Fig. 1) deeply mineralized and of yellow-brown color. In spite of the fact that it has been mineralized *in situ*, the borders are so badly damaged and the entire bone so crushed that it is impossible even to determine with any degree of certainty whether it belongs to the right or the left side. Black (1929) illustrated the in-

ternal surface of the specimen (cf. Black's Plate I, Fig. 1) and gives the following description of the state of the bone: "The adult parietal fragment . . . though massive does not appear to be unduly so. It has evidently been subjected to considerable strain within its matrix and as a result is traversed by numerous fracture lines of varying width and directions, the interstices of which are filled with a travertine of greater hardness than the fossilized bone itself." The only indication as to the orientation of the bone may be provided by the course of the grooves of the meningeal vessels. But on account of the fracturing these impressions, too, are preserved only to a slight extent. So far as may be concluded, their arrangement seems to indicate that the bone is a right one with the posterior ramus of the middle meningeal artery (rp) near the inferior posterior border of the fragment, as shown in Figure 1, and the anterior ramus (ra) near the anterior border which partly coincides with the coronal suture. The outer surface is split even more than the inner one with the superficial layer cracked to a considerable extent. Although the sutures themselves are no longer recognizable, the borders of the fragment seem to coincide fairly well with the sutures. The greatest chord length measured from the upper border—sagittal suture—to the lower one—squamous suture—is 96 mm. and the greatest arc length 108 mm.; the same measurements taken from the anterior border—coronal suture—to the posterior border—lambdoid suture—total 98 mm. and 115 mm., respectively. This corresponds precisely to the size of the parietal bones of Skulls III and XII.

The exact place of the numerous small pieces cannot be determined but they seem to be fragments of the frontal or parietal bone. Three of them are traversed by tortuous sutures already fused which may represent parts of the coronal or sagittal sutures. All show the same degree of mineralization as the main fragments, but their color is more of a yellow-grayish than a yellow-brown texture. Four of the larger pieces show a perfect fit when adjusted and form a part of the frontal bone listed in the Catalogue as No. I, 2. It represents the greater part of the left half of the squama (Figs. 2–4). The total length of the fragment amounts to 71 mm., its total breadth to 49 mm. The entire supraorbital ridge is broken off, but the frontal tuberosity (tf) towards the lateral end of the supratoral sulcus and a part of the temporal surface (ft) are preserved, including the frontal section of the temporal line (lt) with its root at the zygomatic process (pz). The line is well developed. The fragment shows a considerable thickness, amounting to 13 mm. at the medial upper border and to 11 mm. at the lower end of the temporal line.

From the size of the two fragments, particularly that of the parietal bone, it can be concluded that Skull I belongs to an adult or at least adolescent individual. This classification is supported by the degree of development of the temporal line and the thickness of the bones. Although the parietal bone cannot be taken as an absolutely reliable gauge of the thickness of this skull because of its apparent subjection to secondary pressure, the fact remains that it is 14 mm. thick at the angle supposed to be the mastoid. In any case, it indicates a considerable thickness and conforms to the conditions recorded above for the frontal bone. It seems probable, therefore, that Skull I is that of a male individual as was suggested in my list of the *Sinanthropus* population (1935) in which the parietal bone was attributed to the male Individual B II.

Skull II—Skull Locus D—(Figs. 5–16)

Skull II is identical with the Skull of Locus D found in 1929 and recognized as *Sinanthropus* after the removal of the fragments from the adhering matrix. According to Davidson Black

(1930) "the new specimen has been pieced together from uncrushed fragments where broken edges actually fit one another."

Skull II is represented by a skull cap consisting of a part of the frontal bone with the left supraorbital, the two parietal bones, the greater part of the squama of the left temporal bone, three small fragments of the squama of the occipital bone, the upper part of the nasal bridge and the greater wing of the sphenoidal bone. All these bones fit one another, as mentioned by Black, but he is not quite correct in his statement: "No other restoration having been made in the skull. . . ." As Black's photographs (Figs. 5–10) made from the original show, the exterior surface of the inferior half of the left parietal bone was so badly damaged that the defective region had to be filled with plaster in order to make the restoration at all possible.

The mere fixation of the individual fragments, however, proved insufficient in that fairly large gaps remained in certain places. Therefore, a more complete restoration had to be made such as is shown in the drawings of the skull (Figs. 11–16). The bones show a slight yellow color spotted with black. The mineralization is not very pronounced and all the meshes of the cancellous tissue of the diploë being free from matrix. It seems that the skull was more complete when recovered, for the breakages of some of the fragments, as for example the right side of the supraorbitals (Figs. 6; 12), look fresh. This indicates that certain skull parts were broken off in the process of excavation, probably because the specimen was first not recognized as human.

Regarding the individual age, the skull apparently belongs to a "young adult in the first stage of early maturity" as already stated by Davidson Black (1931). Most of the sutures are widely open. But the parietal obliteration of the left coronal suture indicates that the individual must have been more than twenty years old, judging by the conditions of modern man. The determination of sex meets with greater difficulties. Black described the skull first (1930) as representing "possibly a male," then (1931) changed his mind in considering it as a female. This problem will be discussed subsequently.

Skull III—Skull of Locus E

Skull III is identical with Skull of Locus E found in 1929 by W. C. Pei. Davidson Black (1931) has already supplied such exhaustive descriptions of the condition and characteristics of this skull that it will suffice merely to refer here to that author's publication.

Skull IV (Figs. 17–20)

Skull IV is represented by only one fragment consisting of the anterior half of a right parietal bone. This specimen was collected in 1931 by W. C. Pei (1931/32) from the "Quartz Horizon 2" of the floor of the Kotzetang Cave (Locus G). According to Pei three pieces were found *in situ* at a considerable distance from one another. After their preparation the pieces fitted together without leaving any gaps as is evident from Figures 17 and 18 which show the lines of union distinctly. The upper border of the fragment is represented by the well preserved sagittal suture, the anterior border by the coronal suture likewise well preserved and the lower border by the squamous suture. The frontal and sphenoidal angles are broken off; so is the entire posterior half of the bone. The greatest anterior-posterior diameter of the fragments amounts to 68 mm. and the greatest superior-inferior one to 100 mm. The fragment is deeply mineralized and of dark red color.

In regard to age and sex of the individual, the character of the sutures indicate the speciment to belong to a young individual, possibly an adolescent, while the thickness of the bone, totalling 10.7 mm. at approximately the middle of the parietal tuberosity, and the well developed temporal lines suggest a male which I tentatively designated as Individual G II in my paper on the *Sinanthropus* population (1935).

Skull V—Skull III Locus H (Figs. 21–30)

Skull V is represented by two fragments, a large and a small one. The large fragment—Fragment I (Figs. 21–27)—consists of the left temporal bone and the adjoining parts of the parietal and occipital bones. It was found in June 1934 in Locus H, the borders and the two surfaces, particularly the interior, being coated with thick lime crusts. The specimen is completely mineralized and of a light yellowish color, somewhat like ivory. It is well preserved except for the most prominent parts of the outer surface which are smooth and glossy as if polished.

Almost the whole temporal bone is preserved, namely the entire squamous portion—only the zygmotic process is missing,—nearly complete the mastoid portion, the tympanic and the petrous portion—only the apex region of the pyramid is broken off. The preserved part of the parietal bone consists of the inferior and posterior area of the bone: the region of the squamous and lambdoid sutures and the mastoid angle. The preserved part of the occipital bone is represented by a large portion of the left half, except for the surrounding of the occipital foramen. The greatest length of the fragment is 150 mm., the greatest height 90 mm. The bone is rather thick. The thickness of the occipital torus—lateral to the missing midline of the bone—amounts to 15.5 mm. and that of the torus angularis of the parietal bone to 15 mm.

The small fragment—Fragment II (Figs. 28–30)—was recognized in 1936 while the material recovered from Locus H in 1934 was being prepared in the Laboratory. It represents a part of the right temporal bone comprising the entrance to the external acoustic meatus and the region immediately behind and above: the mastoid portion posteriorly and superiorly to the occipitomastoid and parietomastoid sutures, and the inferior part of the squamous portion with the zygomatic process and its continuation, the supramastoid crest. As to the petrous portion only the base of the pyramid is preserved. The greatest length of Fragment II is 69 mm. and the greatest height 55 mm. It is less mineralized than Fragment I and its color is dark ochre.

In spite of the fact that the two fragments do not come from the same level and consequently differ in degree of mineralization and color, they undoubtedly belong to the same individual, tentatively designated as Individual H III in my article on the *Sinanthropus* population (1935). This assumption is based on their almost complete conformity in massiveness, size and appearance of the main features. Like in Fragment I which shows the outer surface to be partly smooth the projections of the exposed sutural borders of Fragment II in some places bear distinct indications of wear. However, there is a difference. In Fragment I all the sutures, particularly the squamous and lambdoid sutures, are closed and the latter almost completely obliterated while the occipitomastoid suture is easily recognizable, especially on X-ray photographs. In Fragment II, on the other hand, this and the parietomastoid sutures were apparently still patent. But such divergencies concerning right and left sides are commonly found in human skulls.

Massiveness and size of the fragments and the strong development of all special structures suggest that the skull must be attributed to a male individual. The conditions of the sutures,

especially as displayed in Fragment I, reveal that the individual had reached a fairly advanced age.

Skull VI—Skull VI Locus I (Figs. 31–36)

Skull VI is represented by four fragments: the right part of the frontal bone (Fragment I), a part of the left parietal bone (Fragment II), a smaller piece of the same parietal bone (Fragment III) and a part of the squamous portion of the right temporal bone (Fragment IV). Fragment III fits perfectly into the inferior end of the anterior line of breakage of Fragment II. But there are no connections with Fragment I or Fragment IV.

All four specimens were derived from Layer 8 (Level 22) and found embedded in black and yellow ashes. Fragments II and III were recovered *in situ;* I and IV were recognized as skull specimens while the material from Layer 8 was being prepared in the Laboratory. All the pieces are deeply mineralized and of grayish color with black spots. The fragmentary condition of the skull is evidently a very old one, occurring long before fossilization took place.

Fragment I (Figs. 31, 34) embraces the left side of the frontal squama and a very small portion of the right side with the mid-line being indicated on the outer surface by a rather faint median crest, more palpable than visible, and on the inner side by the superior end of the crista galli and the beginning of the sagittal sulcus. The supraorbital region is broken off just where the frontal tuberosity starts to decline toward the supraorbital sulcus. A portion of the parietal bone is attached to the lateral posterior margin of the frontal bone as indicated by the course of the coronal suture of which the end of the pars complicata and the entire temporal section is preserved. The suture is fused. The sphenoidal angle of the parietal bone is depressed, apparently due to the fracture.

Fragments II and III (Figs. 32 and 35) consist of the greater part of the left parietal bone. All four borders are broken off, except for a small portion of the squamous suture near its anterior end. In addition, the entire inferior posterior and the posterior regions of the bone as a whole are missing. The posterior half of the superior margin of the fragment shows a peculiar notch with rather irregular borders; starting from its end a narrow and shallow groove (sa) bordered by parallel lines runs toward the posterior fracture of the specimen. Fragments III and II, when attached, fit one another completely on the inner side but not so on the outer one. Here the borders are broken off, particularly around a central point where the crack which separates the two fragments meet with a second fissure crossing the inferior part of Fragment II (Fig. 35, frc). The significance of these injuries will be discussed below.

Fragment IV (Figs. 33 and 36) consists of the anterior part of the squamous portion of the right temporal bone. The piece is broken off just along the sphenosquamosal suture. The posterior part is missing and so is the zygomatic process, except for the foremost part of its root. Attached to the squama is a small piece of the parietal bone and united with it by the completely fused squamous suture.

All four fragments were recovered from the same level (Level 22—Layer 8). Fragments I and IV were found close together while Fragments II and III were collected at a distance of about 14 meters. Nevertheless, these specimens evidently belonged to the same skull. In spite of the fragmentary character each piece points to the fact that the pertaining skull must have been strikingly small. Since the temporal lines and the temporal surface, on one hand, and the middle, on the other, are preserved in the fragment of the frontal bone (Fragment I), it is possible to compute approximately the least breadth of the skull; it cannot have been in excess of 80 mm. Fragment IV permits the measurement of the height of the squamous por-

tion of the temporal bone, taking the zygomatic process as basis and the highest point of the squamous margin as vertex. The distance between the two marks is 37 mm. as against 44 mm. in Skull III. The size of the parietal bone can be inferred from the lengths of the transversal arc and chord of the bone measured from the squamous to the sagittal margins. The first given border is preserved while the latter is missing in Fragments II and III. It has already been mentioned above, however, that the superior border of the fragment apparently runs rather closely to the sagittal suture. Taking this into account, the arc of the bone amounts to c. 94 mm. and the chord to c. 80 mm. as against 100 mm. and 87 mm., respectively, in Skull III. If the occipital bone attributed to *Sinanthropus* Skull VIII (see below), evidently belonging to a child, is disregarded, each of the three skull bones represented by fragments from Level 22 is by far the smallest ever recorded, a fact strongly indicating that they belong to the same skull.

The fusion of the coronal suture in Fragment I and that of the squamous suture in Fragment IV indicates that the individual must have been of fairly advanced age. Thus, such smallness of the bones can only suggest that they belonged to a female—Individual I,I.

Skull VII—Skull I, II (Figs. 37-40)

Skull VII is represented solely by the mastoid angle of a right parietal bone. Like the fragments of Skull VI this specimen also was recovered from Level 22 and recognized as human after its preparation in the Laboratory. It cannot be considered a part of Skull VI, since its dimensions indicate that the parietal bone has been considerably larger than that of the latter represented by Fragments II/III.

The lambdoid, the parietomastoid and the posterior end of the squamous sutures embracing the mastoid angle are preserved. The specimen is moderately mineralized and of ochre color. The fracture separating it from the rest of the parietal bone is apparently an old one. Notwithstanding the fact that the indentations of the sutures are rather marked which in turn indicates their pronounced patent character, the individual must have been of adult age. For some of the processes of the lambdoid suture of the occipital bone are broken off and fused with the denticulations of the parietal bone (Fig. 38) against which they impinge. In regard to sex, size and robustness of the fragment—the thickness within the torus angularis region amounts to 17.4 mm.—prove that the individual was a male. This adult male individual must be distinguished as Individual I, II from the adult female individual known from the fragments of Skull VI (Individual I, I).

Skull VIII—Skull Locus J I (Figs. 41-45)

Skull VIII is represented solely by the central portion of the occipital bone. The fragment is recovered from Level 23 (Locus J) and was recognized as human after preparation in the Laboratory. It is moderately fossilized and of a light ochre color.

The fragment consists of the central portion of the occipital bone including, in its upper region, a small part of the occipital plane and, in its lower one, a larger part of the nuchal plane. No other fragments of an occipital bone were found from the same level. The fractures are evidently old.

The size and fragility of the specimen, especially the thinness of the bone—the torus occipitalis is 7.1 mm. thick within the mid-line—indicate that it belongs to a rather young individual. Since the torus is in its early stage of development, the individual cannot have been more than two or three years old. It is impossible to determine whether it was a male or

female merely on the basis of what is preserved. The individual may be designated as Individual J I.

Skull IX—Skull Locus J II (Figs. 46–48)

Skull IX is represented by one large fragment consisting of the left inferior part of a frontal bone and three smaller pieces which, however, have no connections with one another or the main fragment. On account of their smallness and indefiniteness it is difficult to determine to which cranial bone the smaller pieces belong and can, thus, be omitted from the following description.

All of the pieces were derived from Level 23 (Locus J) and recognized as human after preparation in the Laboratory. They are deeply mineralized and of gray color. The fractures are apparently old ones.

The posterior border of the main fragment in its entire extension is represented by the coronal suture and the inferior border by the sphenofrontal suture. In both cases the processes and denticulations are rather distinct which in turn indicates juvenile conditions. The entire temporal surface is preserved, anteriorly bound by the posterior border of the zygomatic process the rest of which is broken off. The two temporal lines from their starting point at the zygomatic process backwards to the coronal suture are preserved. The remaining part of the fragment consists only of a small area of the frontal squama in immediate contact with the temporal surface.

The dimensions of the fragment, in particular the length of the frontal part of the temporal lines from their origin up to the coronal suture (stephanion), prove that the skull must have been rather small. This length amounts to only 35 mm. against at least 41 mm. in Skull VI and 53 mm. in Skull XI. Correspondingly, the height of the temporal surface measured from the central point of the frontal part of the inferior temporal line to the sphenofrontal suture is only 20.5 mm. against 25 mm. in Skull VI and 29 mm. in Skull XI. In spite of the smallness, the fragment is relatively thick. At the center of the temporal surface the thickness amounts to 5.6 mm. and at the upper end of the fragment, near the frontal tuberosity, to 7.1 to 7.9 mm. These measurements are about the same as in Skull XII but considerably more than in Skull VI in which the thickness of the temporal fossa does not exceed 4.6 mm. I am inclined to deduce from these data that Skull IX belongs to a male child. As was shown above, the occipital bone recovered from the same level (Level 23) also belongs to a child. Nevertheless, the two specimens cannot be parts of the same skull because the dimensions and the thickness of the occipital bone (Skull VIII) are quite inferior to those of the frontal bone. Thus, there must be a difference in age, possibly also in sex between them. I, therefore, consider Skull IX to represent a child of approximately six years of age.

Skull X—Skull I Locus L (Figs. 49–60)

Skull X is the cranium designated as Skull I Locus L in previous publications. The specimen comprises the greatest part of the calvaria. It was recovered from Locus L (Level 25) in November 1936 and identified as human, when still *in situ* (see plan, Figs. 249 and 251), by L. P. Chia, in charge of the field excavations. The skull was badly crushed, but the individual fragments were found close together within loose soil so that their assemblage and readjustment was not too difficult. However, a large number of small particles remain unplaced since they fail to show any connections either with one another or with the larger fragments. Most of them apparently belong to the facial skeleton. Those larger fragments of facial bones, which

could be identified, are listed in the Catalogue of the Facial Bones and will be described below separately. The conditions were furthermore complicated by the recovery of Skull XI, like-wise crushed, at a distance of not more than 50 cm. Fragments of facial bones belonging to this skull were found intermingled with those of Skull X (see below). All of the bones are moderately fossilized and of a yellowish ochre color.

The work of restoration of the calvaria was greatly facilitated by the fact that most of the broken bones had at no time changed their position and could thus be adjusted to one another almost *in situ*. The squama of the frontal bone and the right parietal bone, however, suffered greater damage than the other parts. Gaps remaining between the individual fragments were filled with plaster as is evident from the illustrations. But it should be noted that not all of the restored gaps are as large in reality as they appear. For many of the fragments are in contact with their inner table, since the injuries are confined more to the exterior layer of the bones.

The restored calvaria compromises almost the entire frontal bone including the supraorbitals, except for the lateral portion of the left one; the two parietal bones; the entire squama of the occipital bone; almost the entire right temporal bone and two small fragments of the squamous portion of the left one. The whole base and the pterion region on both sides are missing.

The isolated facial bones undoubtedly belonging to Skull X consist of the frontal process of the left maxilla—Facial Bone No. I (Catalogue, Table I)—and a fragment of the left zygomatic bone—Facial Bone No. II (Catalogue, Table I).

The skull is evidently that of an individual of slightly advanced age. For the bregmatic sections of the coronal as well as sagittal sutures are completely fused, while all of the remaining sutures, as far as they are preserved, are open. Size and robustness of the skull indicate that it may belong to a male individual—Individual L I.

Skull XI—Skull II Locus L (Figs. 61–72)

Skull XI is identical with Skull II Locus L of the previous publications. The specimen comprises the major portion of the calvaria. It was recovered from Locus L (Level 23), in 1936, on the same day as Skull X at a horizontal distance of only 50 cm. from the latter and identified as human, when still *in situ* (see plan, Fig. 249 and 251), by L. P. Chia who was in charge of the field work. Like Skull X this skull was also crushed but the individual fragments were found piled in one place and embedded within loose soil so that it did not prove too difficult to assemble and readjust the pieces. In this case also, numerous small particles remained unplaced, most of which belong to the facial skeleton. Since these pieces were intermingled with those belonging to Skull X, as already mentioned above, their proper identification was difficult.

All parts of the skull are moderately fossilized and of a yellowish ochre color.

The restoration of the calvaria proved easier than in the case of Skull X. The fragments were larger and fitted into another rather well. The only real gap that exists traverses in a wide curve across the posterior part of the left parietal bone and then follows the occipito-mastoid suture.

At the time of the discovery of the skull the right supraorbital was broken off and not among the smaller pieces spread around the main fragments. In the following year, however, when the excavations reached a lower level, the missing supraorbital was unearthed at the same site as the skull but one meter deeper. The restored calvaria is almost complete. It comprises the frontal bone, the two parietal bones, the squama of the occipital bone, including the posterior margin of the occipital foramen and the two temporal bones. Also a part of the left sphenoid

is preserved. The basal parts forward from the occipital foramen are missing. So is the tympanic of the right temporal bone.

The isolated facial bones that can be attributed to Skull XI are a fragment of a left maxilla with five teeth (P^1-M^3) in place—Facial Bone No. V (Catalogue, Table I),—and possibly a fragment of a palate—Facial Bone No. IV (Catalogue, Table I).

Skull XI represents an adult individual of advanced age. This may be concluded not only from the wear of the three upper molars but also from the conditions of the sutures. The coronal suture, at least in its bregmatic section, the entire sagittal suture and the lambdoid portion of the lambdoid suture are completely fused. The other sutures, as far as they are preserved, are open.

As to sex, the smallness of the skull and teeth point to a female individual—female Individual L II.

Skull XII—Skull III Locus L (Figs. 73-84)

Skull XII is identical with Skull III Locus L in the previous publications. The specimen compromises the greatest part of the calvaria. It was recovered from Locus L (Level 23) in 1936, that is to say, at the same level as Skulls X and XI, only eleven days later. The horizontal distance from the first site is 6-7 meters (see plan, Figs. 249 and 251). This skull, too, was identified as human by L. P. Chia, when still *in situ*.

As was true of Skulls X and XI, Skull XII was crushed, but the isolated fragments were found in one place and, since they were embedded within loose soil, it was easy to assemble and readjust them. But unlike the conditions of those first skulls, in this case no fragments of facial bones or teeth were found nearby.

The skull is moderately fossilized and of a reddish ochre color.

Notwithstanding the fact that the bones, especially the parietal bones, were broken into many rather small pieces, the restoration did not prove too difficult since the fragments, with only a few exceptions, were in their natural position. A transverse suture crossing the occipital plane of the occipital squama indicates the presence of a large "os epactale" which could not be found among the fragments, however. The region of the frontal squama near the coronal suture was badly damaged, apparently caused by a stroke from the pickaxe when the skull was excavated. This injury constitutes one of the very few gaps.

The restored calvaria is fairly complete. The frontal bone is preserved almost in its totality, including the entire orbito-nasal portion. Furthermore preserved are the two parietal bones, the left temporal bone, the entire squama of the occipital bone including the posterior margin of the occipital foramen and the posterior part of the left greater wing of the sphenoidal. The right temporal bone, almost the entire sphenoidal, the body and the lateral parts of the occipital bone and, as already mentioned above, the apical region of its squama are missing. As to the facial bones, the upper halves of the nasal bones and the part of the left zygomatic bone that forms the lateral and inferior marginal regions of the orbit are preserved.

Skull XII evidently belongs to a rather young individual. All sutures are widely open with no traces anywhere of a beginning obliteration. On the other hand, the considerable size and robustness point against this skull belonging to a child. I am, therefore, inclined to consider the skull as that of an adolescent male individual because of the remarkable roominess of the cranial vault and the apparent massiveness of the bones, particularly so when compared with the female Skulls VI and XI. The individual will be known as male Individual L III.

Skull XIII (*Figs. 142–147*)

Skull XIII is represented merely by the fragment of a left maxilla with six teeth—I², P¹ to M³. The maxilla was recovered in 1937 from Level 29 (Locus O) by L. P. Chia. It was broken into several pieces and the teeth out of the alveoli, except for P¹ and P² which were still embedded within their sockets.

The specimen is deeply fossilized and of a yellowish ochre color. The breakages are evidently old. The fragment consists of the inferior parts of a left maxilla comprising the alveolar process, the lateral portion of the palate process, the facial surface from the anterior nares to the zygomatic process and the greater part of the zygomatic surface. The medial incisor and the canine are missing and the anterior wall of the canine socket is broken off, while the socket of the medial incisor is preserved with the upper portion of the posterior wall. The entire maxillary tuberosity together with the socket of the third molar is also broken off, but the tooth itself is preserved. On the medial side of the fragment the palatine process with the palatine canal is preserved and likewise the anterior part of the inferior meatus up to the infraturbinal crest, while the remaining lateral wall of the inner surface is broken off and the cavity of the maxillary sinus widely exposed.

Skull XIII undoubtedly belongs to an adult individual as is revealed by the teeth. Since the latter show considerable wear the individual must have been of fairly advanced age. As to sex, the size of the teeth indicate that it probably belonged to a male individual—male Individual O I.

Skull XIV (*Figs. 153–156*)

Only with certain reservations Skull XIV is included within the list of *Sinanthropus* skulls; it is represented solely by the fragment of a left maxilla with four teeth—P¹; M¹-M³.

The maxilla was recovered, in 1933, from the "Upper Cave" of Choukoutien by W. C. Pei together with the skeletons of the Upper Palaeolithic Man of the Upper Cave (cf. Weidenreich, 1939b, and W. C. Pei, 1939b; 1940). In examining and studying this material I was deeply impressed by the appearance of this specimen; it distinctly differs from the other bones found in this cave by the high degree of mineralization, the special color, the primitiveness of the form, the considerable size of the teeth and the way in which the bone is broken. In all these particularities the maxilla shows a greater resemblance to the *Sinanthropus* jaws recovered from Locality 1 than to the maxillae of the Upper Cave Man which have been found in connections with their pertaining skulls. The possibility that the maxilla in question really belongs to *Sinanthropus*, notwithstanding the site it was derived from, exists. For the Upper Cave is to a certain extent a cavity secondarily formed within the deposits of the main cave (Locality 1) of Choukoutien; their walls partly consist of soil deposited earlier in Locality 1 and may, therefore, well contain *Sinanthropus* bones mingled subsequently with those of the later dwellers of the "Upper Cave."

Strangely enough, the fragment of the maxilla bears a close resemblance to that of Skull XIII; it is the same side and consists mainly of the alveolar process and the lateral portion of the palate process. The lateral inferior part of the piriform aperture is preserved and partly the alveoli of all the teeth, except that of the medial incisor. As to the teeth, the three molars and the first premolar were found separated from the jaw, but they could be fixed into their sockets without any difficulty. More details will be found in the next chapter.

Skull XIV represented by the maxilla fragment undoubtedly belongs to an adult individual of advanced age, as is proven by the teeth and their degree of wear. As to sex, the size of the teeth indicates that it probably belongs to a male individual—male Individual U. C. (Upper Cave).

Facial Bones

Under this caption reference will only be made to such facial bones which were not found in connection with skull parts. The condition of facial bones still in contact were described in the preceding paragraph. Only two cases fall within the latter category, namely (1) the upper part of the nasal bones attached to the frontal bone of Skull II and (2) the nasal bones and a large part of the left zygomatic bone attached to the frontal bone of Skull XII.

There are six isolated facial bones large enough to be identified as such (cf. Catalogue of Table I). Nos. I and II represent the frontal process and the adjoining part of the body of a left maxilla and a fragment of a left zygomatic bone, respectively, belonging to the male Skull X (see above). No. III, the fragment of a left maxilla with the five teeth: P^1-M^3, belongs to the female Skull XI (see above). Approximately one half of the palate, designated as No. IV, could not be determined as to whether it belonged to Skull X or XI (see above). No. V, fragment of a left maxilla with six teeth: I^2, P^1-M^3, has been described as Skull XIII above, and No. VI, fragment of a left maxilla with the four teeth: P^1, M^1-M^3 as Skull XIV.

No. I (Figs. 135 and 136) consists only of the frontal process and the adjoining part of the body of the left maxilla upwards to the frontomaxillar suture, medially to the nasomaxillar suture and backwards to the lacrimomaxillar suture. The medial end of the infraorbital margin and the superior lateral border of the nasal aperture are preserved.

No. II (Figs. 160–163) consists of the major part of a left zygomatic bone, the infraorbital margin and a small portion of the orbital process being preserved. Medially the fragments reach up to the maxillozygomatic suture. The frontal and temporal processes are broken off.

No. III (Figs. 148–152) consists mainly of the alveolar process of a left maxilla with small portions of the palate and zygomatic processes. The anterior portion of the alveolar process forwards from the posterior wall of the socket of the first premolar and the posterior end, together with the maxillary tuberosity, are missing. The three molars and the second premolar are preserved within their alveoli. The first premolar the crown of which is damaged was found separately but could easily be fixed into the remaining portion of its socket.

No. IV (Figs. 157–159) is approximately the right half of a palate extending from the lateral incisor backwards to about the level of the second molar border and from the medial border of the corresponding alveoli to about the sagittal palatine suture.

No. V (Figs. 142–147) see above under Skull XIII.

No. VI (Figs. 153–156) see above under Skull XIV.

C. Identification and Reconstruction

The identification of isolated and broken cranial and facial bones of *Sinanthropus* is not rendered any too difficult provided the fragments are large enough or display characteristic details. In identifying small calvaria fragments of young individuals, however, there is the possibility of mistaking mammalian remains as human, for example, those of bear. A careful and thorough examination will insure a correct diagnosis in most of these cases. If any doubt remained, the questionable specimens were placed aside.

As was pointed out in the preceding chapter, Skulls X, XI and XII were recovered in badly crushed conditions, apparently due to the weight of the matrix pressed against them. However, since the fragments were not scattered but rather preserved in their original resting place, the reconstruction could be confined solely to the readjustment of the various pieces. As is evident from the illustrations of the skulls, certain gaps nevertheless remained in such places where the borders of the fragments were splintered and consequently lost. On the reconstruction these empty spaces were filled in with cement and colored in lighter tone so as to accentuate the extent of the defects. Boule (1937) referring to few photographs given in my preliminary note (1937c) infers that these gaps may influence form and size of the skulls to such an extent as to make any exact estimation of their capacities impossible. In reality, however, the gaps are restricted to rather limited areas of the cranial surface. Form and size of the calvaria can easily be ascertained on the basis of those large fragments which are in direct contact with each other. Moreover, in the drawings of the skulls all major fractures and gaps are distinctly marked to enable the reader to form his own opinion as to the reliability of the reconstruction.

Reconstructions on a larger scale were carried out only in the cases of Skulls V (H III) and XI (Skull II Locus L). Since Skull V is represented solely by the left temporal bone with the adjoining parts of the parietal and occipital bones (Figs. 21 and 23), the reconstruction was restricted to the contour of the left norma lateralis (Fig. 85) and the left side of the norma occipitalis (Fig. 23). The size of the temporal bone totally preserved in this fragment indicates that the calvaria is by far the largest within our collection. For comparison with other calvariae, at least its length, breadth and height must be ascertained. As large parts of the parietal and occipital bones still adhere to the temporal bone, it was not too difficult to determine the natural orientation of the fragment within the calvaria, and to complete the course of the outlines in lateral and occipital normae according to that of the fragment. Height and breadth could be calculated on this basis (cf. Fig. 23); Skull III served as standard in estimating the length and the contours of the missing bones anterior to the sphenosquamosal suture.

Skull XI was taken as basis for the reconstruction of an almost entire skull of *Sinanthropus*, including the face (Figs. 86–89, and Weidenreich, 1937a)—see the special chapter in Part II. Except for minor details, unessential to the skull as such, I refrained from reconstructing those parts of which the special forms were not verified by actual finds. Thus, the entire base anterior to the posterior margin of the occipital foramen and the pterygoid process were omitted. For all of the remaining cranial parts missing in Skull XI, Skulls II and XII served as models. Since, in view of their sizes (see above), Skull XI had to be regarded as representing a female individual and Skulls III and XIII as males, the reconstructed parts were necessarily made in proportion to the chosen standard.

As to the facial skeleton, most of the essential components are preserved. They are partly in immediate connection with the cranium as in the case of male Skull XII or partly belong to female Skull XI or to male Skull X, and consist of the nasal bones and almost the entire maxilla and zygomatic bone. Since all of these available bones happen to belong to the left side only, the entire right had to be reconstructed on their basis. In these cases the restored parts were necessarily adapted to the standard size. As mandible Mandible H I could be used (cf. Weidenreich, 1936b) without any other alteration but that of adapting it to the breadth of the cranium.

Therefore, the face as is illustrated in Figs. 85 and 87 represents in all its part and details a true aspect of a *Sinanthropus* face. Only two of the features remain not verified by actual finds, namely: the facial region just above the infraorbital foramen and the major portion of

the zygomatic arch.   The special appearance of the first feature can easily be deduced from that of the preserved adjoining parts of the maxilla.   Height, thickness and the form of the contours of the arch are fictitious.   However, since the height and thickness of the root of the temporal process of the zygomatic bone as well as those of the zygomatic process of the temporal bone are given, the eventual error cannot be too significant.

More important than these peculiarities is the general direction of the arch.   Since level and orientation of the temporal end of the arch is preserved in direct connection with the calvaria in five cases (Skulls II, III, X, XI, XII), partly even of either side, the direction is chiefly dependent upon the height of the zygomatic bone.   In Skull XII the part of the inferior margin of the orbit or at least the one very close to it is preserved together and in connection with its superior and lateral margins (Figs. 73, 75 and 79, 81).   This allows us to locate fairly accurately the "orbiculare."   On the other hand, the fragment of the zygomatic bone (Facial Skeleton Bone No. II—Figs. 160–163) includes not only the orbiculare but also the lowest point where the zygomatic arch meets the lateral margin of the body of the bone.   Therefore, the frontal process of the zygomatic bone of Skull XII in connection with the cranium, on the one hand, and the zygomatic fragment No. II, on the other, unquestionably indicate the direction of the arch.   When the Frankfort Horizontal, which is defined by orbiculare and porion, both of these landmarks being present in Skull XII, is taken for orientation of the skull, the zygomatic arch fails to run parallel to it but rather slants distinctly toward the front (Fig. 86).

The reconstruction of Skull XI was carried out with the kind assistance of the sculptress Mrs. Lucille Swan, Peking.

THE STRUCTURAL CHARACTER OF THE SINANTHROPUS SKULL

A. MORPHOLOGY

I. CALVARIA

The following description of the *Sinanthropus* skull is chiefly based on the more or less complete calvariae of Skulls II, X, XI and XII with occasional reference to Skull III described by Davidson Black (1931) as Skull of Locus E. The first paragraph deals with the aspect of the skull as it appears in lateral, frontal, occipital, vertical and basal views, taking into account only its general form and the most characteristic features peculiar to all skulls available. The different variations, as far as they are of particular interest, are discussed in the following paragraph where special consideration is given to the separate bones of the skulls, including also the cranial fragments as represented by Skulls I, IV, V, VI, VII, VIII and IX (see Table I and under A).

1. General Aspect

In order to provide as common and uniform a pattern as possible for the *Sinanthropus* calvariae the Frankfort Horizontal plane was used throughout, not only for the two lateral but also for the frontal, occipital, vertical and basal aspects. The accurate determination of this plane, of course, is only possible in such cases in which orbiculare and porion are preserved. As already mentioned above, this eventuality occurs solely in Skull XII, the inferior margin of the orbit and thus the orbiculare being missing in all of the other instances. Nevertheless, the location of this landmark can be calculated on the basis of the height of the orbit, a measurement for which Skull XII furnishes a reliable gauge. The height of the orbit corresponds approximately to the vertical distance of the orbiculare from the highest point of the superior margin of the orbit which is preserved in Skulls II, III, X and XI. This distance amounts to 38 mm. in Skull XII. A *Sinanthropus* calvaria with the orbiculare missing but with the supraorbitals preserved *in situ* can, therefore, easily be placed in an approximately correct position if the highest point of the superior margin of the orbit is brought to stand about 38 mm. above the horizontal plane laid through the porion. All of the skulls are oriented in this way. Black used almost the same orientation in describing Skull E (1931).

Norma lateralis

(Figs. 5, 6; 11, 12; 49, 50; 50; 55, 56; 61, 62; 67, 68; 73, 74; 79, 80)

The most striking characteristic of the *Sinanthropus* skull in norma lateralis view is its shape as accentuated by the outlines. The skull is rather low in proportion to its length, the torus supratoralis in front and the torus occipitalis in the back forming the utmost prominences in anterio-posterior direction. The greatest length, therefore, coincides with the glabello-inion plane (regarding the definition of the inion see later). The torus supraorbitalis is a rather bulky formation with a well developed, almost horizontal superior surface. Above the torus the outline rises rather abruptly to a very distinct, rounded eminence; yet considered as a whole, the forehead itself is prone and distinctly receding.

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The vertex region, which either coincides with the bregma or is somewhat behind, appears as a shapely arc. In Skulls II, X and XII the rounded contour is continued backward to the lambda while Skull XI displays a distinct obelion depression such as described by Black in Skull III. Immediately behind the lambda the contour rises to a distinct eminence corresponding to the upper portion of the occipital planum. Then follows a second still more pronounced bulging which represents the occipital torus. The incurvation between these two projections is the sulcus supratoralis (see Weidenreich, 1940b, and later). Beyond the occipital torus the contour bends rather sharply forward forming a fairly acute angle between the occipital and nuchal planes. The acuteness, however, is less a consequence of the flatness of the nuchal part but rather due to the lowness and proneness of the upper portion of the squama beyond the torus. In skulls which are higher on the whole, like Skull X, the angle is considerably greater. This was certainly also true of Skull II in which, however, only the apical region of the occipital squama has been preserved.

In accordance with the sharply receding forehead the bregma is situated almost vertically above the porion. The temporal line—or lines, if two can be discerned—forms a wide flat arc very close to the midline. In some cases the posterior superior section of the line rises to a real ridge which merges in a fairly circumscribed tuber-like elevation, occupying almost the entire mastoid angle of the parietal bone (see later). I designated this rather characteristic feature of the *Sinanthropus* skull, already noted by Black, "torus angularis" (Weidenreich, 1940b). The squama of the temporal bone is very low and the arc formed by the course of the squamous suture is as flat as that of the temporal line. The highest point of the arc is closely behind the krotaphion.

The pterion region is only preserved in Skull XI (left side) and Skull XII (left side). In the former it shows, as already described by Black for Skull III, the typical human pattern or, in other words, there is a well developed sphenoidal angle which lies between the frontal bone and the squama of the temporal bone and joins with the great wing of the sphenoid. The smallest distance between the frontal and temporal bones is 7 mm. The coronal suture in Skull XII is widely open, and the uppermost part of the sphenoid is broken off. Nevertheless, it may be concluded that in this case also a human pattern had existed, although the intercalated sphenoid portion was certainly not broader than 3–4 mm.

In almost all cases in which the vertical part of the great wing of the sphenoid is preserved in connection with the squama of the temporal bone (Skulls II, III, XI, XII) the whole sphenosquamous juncture projects while the sphenoid itself slopes abruptly to a deep and relatively narrow temporal fossa. In addition, the anterior portion of the squama is more or less bulging and with it increases the steepness of the slope leading to the temporal fossa. This feature is particularly pronounced in Skull II but manifest to a lesser degree in all skulls. Black called attention to the fact that on the lateral surfaces of Skull III irregular ridges occur which course in a general direction parallel to the line of the zygomatic crest. The same feature is found in Skulls II, X and XII. In these cases one ridge exceeds the other. In Skull XI, probably representing a female individual, the ridges are also present but much less developed.

The base of the zygomatic arch is more or less preserved in Skulls II, V, X, XI and XII. In all cases it runs in a rather pronounced oblique direction and continues backwards into a strongly developed supramastoid crest which ends abruptly at the parietotemporal suture above the parietal notch. Skull X (right side) and XI (right side), where the edge of the supramastoid crest above the auditory meatus is preserved, show the extent of its outward projection above the porion to amount to 10 mm.

The external auditory meatus is rather deeply sheltered beneath the overhanging root of the supramastoid crest. If the center of a line linking the anterior and posterior points, where the lateral border of the tympanic plate joins the roof of the meatus, is taken as landmark for the deepest point, and the point where the interporial transverse plane cuts the edge of the supramastoid crest as the most superficial one, the depth of the roof amounts to 10–18 mm. (against 3–8 mm. in modern man). In none of the other skulls does the tympanic plate exhibit a division into an anterior and posterior moiety such as described by Black for Skull III; the floor of the meatus is continuous in all cases, with the exception of Skull XI wherein the lateral border of the tympanic shows a deep indentation in exactly the same place where the cleavage is found in Skull III.

Like Skull III, none of the skulls displays a true postglenoid process, the partition between the mandibular fossa and the entrance to the porus being formed merely by a broad-based and low triangular projection the medial end of which directly joins the lateral border of the anterior lamina of the tympanic plate or extends a short distance medianward in front of the latter (see later).

The mastoid process is well developed and accentuated by the existence of a pronounced mastoid crest and a wide digastric fossa. The inferior part with the mammillary portion is broken off in all cases, but it can be deduced from the dimensions of the breakage that that portion must have projected downwards considerably in the male Skulls V, X and XII but much less so in the female Skull XI. One particularity of the process is common to all skulls: it does not descend vertically as is the rule in modern man but bends inward sharply below the level of the mastoid crest.

Norma frontalis

(Figs. 7, 13; 51, 57; 63, 69; 75, 81)

In cases in which one or the two temporal bones are preserved, the frontal view of the skull is characterized by the particular course of the outline. The greatest lateral projection is found at the level of the supramastoid crest. From this mark the line recedes medianward continuously with two more distinctly pronounced bends in its course, the first occurring immediately above the crest and the second higher up coinciding with the vertex of the parietal tuberosity. In other words, the breadth of the calvaria is greatest at the biauricular plane, gradually decreasing toward the top (Skull V, Fig. 23). This peculiarity seems to be most marked in Skull XII and least in Skull II; it must be recalled, however, that in the latter case the supramastoid crest itself is not preserved, and the restoration of the region in question not reliable (see above).

The second peculiarity is the lowness of the forehead and the narrowness of the calvaria above the supraorbital level. The first feature is, of course, a consequence of the lowness of the entire skull as already emphasized in the description of the norma lateralis; the second is a consequence of the aforementioned particular shape of the skull.

Another peculiarity is a well developed sagittal crest combined with a distinct flattening of the crown on either side of the crest (parasagittal depression). The crest consists of a low, broad-based and blunt ridge which starts from the frontal tuberosity, is highest within the bregma region and becomes imperceptible within the obelion region. The sagittal suture runs along the crest, and the same is true of the metopic one still patent in Skull XI. In all of the skulls there is a slight elevation where the coronal suture meets the sagittal suture or, in other words,

the parasagittal depression is interrupted within the bregma region which thus represents a cross-like elevation. This formation is especially pronounced in Skull XI.

All of *Sinanthropus* skulls show the crest and the parasagittal depression in various degrees of development; in Skull II both features are only slightly developed, yet easily recognizable. There is no distinct differentiation in regard to age and sex. It is true, an infant stage is not preserved but Skull III and the parietal fragment of Skull IV (Figs. 17–19) both of which belong to juvenile individuals exhibit crest and depression not less distinct than Skulls X and XI which bear evidence of an advanced age. With respect to sex, the female Skull XI fails to reveal a distinctly inferior development of the features in question when compared with the male Skull X.

The existence of a median frontal tuberosity has already been noted above. This tuberosity consists of a distinct bulging of the inferior portion of the squama in its entire extent from one temporal line to the other. The eminence is all the more pronounced as the supraorbital ridges which form the very base of the forehead are separated from the squama proper by a broad sulcus, and as, on the other hand, the parasagittal depressions flatten the calvaria just behind the bulge. As the sagittal crest descends towards the tuberosity area it appears to divide the frontal eminence at least in its supreme portion into a right and left one. But to speak of two eminences does not seem justified since the undoubtedly continuous main portion is located below the termination of the crest and its most salient part lies within the mid-line.

Like all other features, there is a great variability in the development of the frontal eminence. It is best developed in Skull III and XI, slightly less in Skull II and XII and least in Skull X in which the whole frontal squama is more erect and more uniformly bulging than in the remaining skulls. The eminence with its abrupt bulging above the supraorbital sulcus appears to be specific to *Sinanthropus*. Even in those small fragments of the frontal squama as are preserved in Skulls I (Figs. 2–4) and VI (Fig. 34) the characteristics of the eminence can easily be distinguished.

The torus supraorbitalis constitutes one of the most striking features. It occupies not only the base of the frontal squama in its entire breadth but projects sidewards considerably beyond the lateral limits of the squama. The ridge is a continuous formation, not restricted to the supraorbital margins as suggested by the term but occupies also the glabellar region. However, since the median portion bends downwards, the torus appears to consist of three sections: two lateral, the supraorbitalis proper, and one median, the glabellar part. The sulcus, already mentioned above, which separates the torus from the ascending part of the squama is very pronounced in the lateral sections because of the supraorbitals being sharply arched upwards while in the glabellar section a more gradual transition takes place.

In Skulls II, III, X, XI and XII the nasofrontal suture is entirely or partly preserved; the same is true of the zygomaticofrontal suture, as far as Skulls III, X, XI and XII are concerned. In Skull XII the entire roof of the right orbit leading to the superior fissure, including the optic foramen, is preserved, and not quite so far of the left orbit. For these and other details the reader is referred to the description of the separate bones and the facial skeleton.

In frontal view the parietal tuberosity appears as a characteristic feature. The more pronounced the above-mentioned parasagittal depression is, the more the tuberosity is accentuated (cf. Figs. 63 and 69). The relation of the temporal line to the tuberosity varies. In cases (Skulls II, X, XII) in which only one line is distinguishable the line traverses the vertex, in those cases in which two lines have developed (Skull III, parietal fragment Skull IV, Skull XI) the linea inferior follows the same course while the superior one runs above the vertex.

Norma occipitalis

(Figs. 8, 14; 23; 52, 58; 64, 70; 76, 82)

The general form of the *Sinanthropus* skull as shown in occipital view is, of course, identical with that of the frontal view. Yet the occipital view is more impressive since it presents the skull in its entire height from top to base, uninterrupted by supraorbitals and defective facial parts.

If Skull XI (Figs. 64, 70) is taken as standard, the skull is rather low in relation to its bi-auricular breadth. The outline demonstrates that the breadth is greatest at the biauricular plane and from there gradually decreases toward the top which is crowned by the sagittal crest. Below the biauricular plane the outline also bends medianwards, indicating that the mastoid process closely follows the contour of the entire mastoid portion of the temporal bone and does not descend in vertical direction, independent of the latter, as is the rule in modern man. The parasagittal depressions are well developed and so are the parietal tuberosities the vertex of which coincides with the sharp median bend of the outline. Below the tuberosities the wall of the vault slopes outward toward the supramastoid region.

The most striking feature is the torus occipitalis. It appears as a continuous broad bulge with a smooth surface which crosses the occipital bone in its entire breadth between the two asterion ridges. The elevation is highest within its central portion and lowers somewhat toward the margins. It courses fairly straight, except for a slight downward curving toward the ends. At its superior margin the entire torus is separated from the occipital plane by a distinct furrow which I termed (1940b) "sulcus supratoralis." Not in all cases, however, does such a line demarcate also the inferior margin of the torus. What might be called a line is found in Skulls III and XI expressed by a faint ridge marking the border between the posterior and inferior surfaces of the torus. In Skulls V, X and especially XII, however, a rather sharply arched line is developed on either side which meet each other within the midline to continue downward into a faint median nuchal line. These transverse lines correspond to the superior nuchal lines of modern man, but there is no external protuberance. In no instance, however, do the lines mark the inferior boundary of the torus which in reality gradually slopes and fades out toward the nuchal plane; they merely represent the upper bounds of the muscular impressions which occupy the nuchal plane and extend upwards to the inferior part of the torus. Neither does an inferior nuchal line exist. Its place is occupied by a more or less distinct rough elevation crossing the nuchal plane.

Immediately beyond the lambdoid suture the torus angularis (see above) rises as a rather marked feature; the temporal line or, more correctly, the superior temporal line takes its origin from the upper end of this boss.

The posterior section of the sagittal suture and the entire course of the lambdoid suture may be seen in occipital view. The former fails to show any peculiarity worth noting. The latter, when compared with the condition of modern man, appears simple in all three sections, especially in the central and asterical sections. Small Wormian bones are rather rare; only in Skulls X and XII were these found near the asterion, incidentally in almost exactly the same place in both skulls. On the other hand, the superior part of the occipital planum is in four of the *Sinanthropus* skulls entirely or partly separated from the remainder by an accessorial transverse suture. The whole occipital planum is involved in Skull X. On either side, starting from the asterion, there is a suture which runs straight medianward for about 15 mm. On the

left side within the same level a gaping fissure begins just beyond the medial end of the lateral suture and traverses the bone up to the midline where it terminates at a median sagittal cleft. At this cleft a second transverse fissure emerges coursing in the same direction as the first one toward a second sagittal cleft where again it ends. However, this second transverse fissure does not gape like the first one. As to the interpretation of this fissural system, the two sagittal clefts are apparently artificial and were caused by crushing of the skull. But this does not apply to the transverse fissures. The left one which gapes on the exterior surface fails to show any indication of its edges having been broken off. Therefore, I consider this fissure, like the lateral vestiges of the transverse suture, as the non-closed portion of an original sutura mendosa which crossed the bone along the torus occipitalis separating the occipital planum from the nuchal one. In my opinion, the transverse fissure on the right side must also be considered a vestige of the same suture which may not have been completely closed and consequently broke when the skull became crushed. In other words, Skull X shows a genuine "Inca bone" which has become partly united with the remaining bone.

This interpretation is strongly supported by facts presented by Skulls XI and XII. In the former there is unquestionably an accessory transverse suture which separates a large interparietal bone from the planum occipitale. The suture which measures 70 mm. shows characteristic serrations in its left half while appearing linear in its right one. On the left side the suture is widely patent, but on the right it is partly obliterated. This is all the more surprising as the lambdoid suture itself is completely fused. Considering location and size of the interparietal bone it may be classified as "os epactale." The term in R. Virchow's, Le Double's (1893) and Gstettner's (1917) sense of the word (see later) should be applied only to such Wormian bones which occupy the very apex and are independent ossifications of the fontanel. This is certainly not the case in our instance. The piece in question is much too large with the base of the triangle measuring 70 mm. and the height 22 mm.; or 48 per cent of the entire height of the occipital planum, taking the torus center as base.

Almost an identical feature is revealed in Skull XII. In this case the interparietal bone is lacking, but its site is indicated by a triangular interstice sharply bordered by the lambdoid suture and a transverse irregular line which forms the base and shows all peculiarities of a genuine suture. The length of the base of this interparietal bone measures about 55 mm. and the height 24 mm. or 44 per cent of the entire height of the occipital planum. The missing bone in this case was somewhat smaller than the os interparietale of Skull XI but evidently of the same character. It became lost because of the juvenile character of the skull with all its sutures widely patent. On either side of the same skull an additional suture can be seen to cut in just at the level of the asterion and to course for a short distance—about 10 mm.—in transverse direction. This suture apparently is also the vestige of a sutura mendosa.

In Skull II almost the entire occipital bone is missing. But of the right side a fragment adjoining the asterion region is preserved. It shows a fused transverse suture (Fig. 14, sm), evidently the lateral end of a sutura mendosa. Skull III is the only *Sinanthropus* skull with a preserved occipital bone where an interparietal bone and vestiges of a transverse suture are absent. Whether this statement can be extended to Skull V (Fig. 23) in which only the greater part of the left side of the occipital bone is preserved is difficult to say. The lambdoid suture is so completely fused in this case that even if a lateral end of the sutura mendosa actually existed, it is no longer recognizable.

Norma verticalis

(Figs. 9, 15; 53, 59; 65, 71; 77, 83)

The shape of the *Sinanthropus* skull viewed in norma verticalis is rather characteristic. The most striking feature is the wide flare of the supraorbital torus in sagittal as well as in lateral direction. The glabellar portion of the torus does not recede when compared with the supraorbital ones but projects to the same frontal plane as the latter or even beyond it. The postorbital constriction is very pronounced. Behind the constriction the skull widens considerably; in those cases in which the root of the zygomatic process is preserved the maximum transverse diameter coincides with the biauricular breadth, but in such where the zygomatic process is missing this diameter falls farther back, at the level of the torus angularis. Behind this plane there is a slight but distinct occipital constriction corresponding to the asterion region, and then the contour again bulges like a "chignon" placed on the occiput. This general projection is still more accentuated by the strongly developed occipital torus.

If G. Sergi's schemata of the diverse forms of the modern skull are applied to that of *Sinanthropus*, the latter may best be ranged among the "Ellipsoides." But it must be borne in mind that such a comparison can only refer to the postorbital part of the calvaria since the supraorbitals which characterize the preorbital part of the *Sinanthropus* skull have no equivalent among modern man. A second difference concerns the horizontal plane to which Sergi's schemata refer. These schemata refer to a much higher level than the horizontal outline of the *Sinanthropus* skull; they coincide with the level of the parietal tuberosity but in the latter with the mastoid angle of the parietal bone.

Although the zygomatic arch is lacking in all cases, the wide lateral flare of the supraorbitals, on the one hand, and the far projecting roots of the arch, on the other, in concurrence with the deep postorbital constriction indicate that the arch bridged the temporal fossa for a considerable distance from the wall of the skull. The breadth of the calvaria in horizontal planes above the level of the arch is notably narrower than that of this level, so that the entire course of the zygomatic arch is widely exposed to vertical view instead of being hidden by the parietal bulge as is the rule in modern man.

The sagittal crest and its cross-like character at the bregma is clearly shown in vertical view, and likewise are the sagittal, coronal and lambdoid sutures. In Skulls X and XI in which these sutures are intact or partly closed, it is possible to determine the degree of their serration according to Stephanie Oppenheim's classification (cf. R. Martin, 1928). In regard to the sagittal suture the bregmatic section is not linear as is the rule in modern man but largely meandrine, and the same is true of the bregmatic section of the coronal suture. But there may be a great variability. In Skull XI the metopic suture is preserved; it is distinctly fused and fairly winding in its bregmatic section while in its remaining ones the bone was broken along the suture; yet it may safely be said that the suture was slightly serrated in its superior and middle sections but linear in the inferior one. Whether the suture was completely obliterated in the torus region and later broken again along this line, as it actually appears, is difficult to determine.

A parietal foramen similar in size to that of Skull III described by Black is only recognizable on the right side of Skull XI and missing in all of the other skulls. This implies that in five *Sinanthropus* skulls in which the parietal region concerned is preserved, the foramen is present only in two cases and only on one (right) side. In addition, the formen is rather small. Ac-

cording to T. Edinger (1933, see the bibliography there) the parietal foramen is a normal occurrence in modern man where it is recorded in 66 per cent while, in anthropoids, it is found only in 18 per cent.

A depression in the obelion region such as is present in Skull III is also found in Skull XI but not in the remaining skulls. The description Black gave of it for Skull III, however, does not apply to the conditions of Skull XI. For in the latter case it is not represented by a "clearly marked oval depressed area" but rather by a general flatness which also involves the entire apical region of the occipital squama.

Norma basalis

(Figs. 10, 16; 54, 60; 66, 72; 78, 84)

The basal view of the skull, of course, is identical with that of the vertical view as far as the contour and the general form of the skull defined by this line are concerned.

The bulge of the supraorbital torus on the front and that of the occipital torus on the opposite end of the base are the most characteristic features. The superior margin of the orbit shows the supraorbital notch and the supraorbital process (see later) rather distinctly, contrary to the conditions noted in Skull III; the frontal sinuses of Skulls II, X, XI, and XII are small in breadth as well as depth and remain strictly confined to the nasal portion; in no case do they extend lateralwards over the roof of the orbit.

The orbital roof in all of the adult *Sinanthropus* skulls is surprisingly flat in sagittal as well as transversal direction, particularly as far as its anterior part is concerned. While in modern man the roof sharply ascends behind the superior margin of the orbit, it hardly rises in *Sinanthropus*. The posterior part of the orbital roof is preserved in Skull XII only (Fig. 84, right side). It shows the optic foramen and the optic canal up to the lateral end of the sulcus chiasmatis. The greater part of the lesser wing of the sphenoid is broken off, but roof and walls of the two roots which enclose the canal together with the edge which borders the superior orbital fissure are preserved. Laterally, the sphenoidal margin of the frontal bone is exposed in its entire extension. It is a triangular rugged surface, rather large especially in sagittal direction when compared with the same surface in modern man. Its apex constitutes the lateral or, more correctly, the superior border of the superior orbital fissure. The distance between the aperture of the optic foramen and the beginning of this rugged surface is extremely limited, measuring only 3.5 mm. This indicates that the orbital fissure was not a long slit, extending between the lesser and the greater wings as is true in modern man, but rather a small opening, similar in size to that of the optic foramen occurring in gorilla and chimpanzee. The sphenoid portion of the orbital roof is so completely fused with the frontal orbital plate that the sutures are no longer recognizable.

In Skull II and partly also in Skull XI the temporal and infratemporal surfaces of the greater wing of the sphenoidal bone are preserved. In Skull II (Fig. 16) the latter is present from the entrance to the pterygo-palatine fossa to the anterior border of the foramen ovale, and medialwards to the base of the pterygoid process. There is no crista infratemporalis but merely a faint linear elevation which separates the two surfaces from each other.

As to the base of the temporal bone, there is in all cases a well developed tuberculum articulare and a deep but narrow mandibular fossa already described by Black as characteristic of *Sinanthropus*. The fact that no trace is to be found of a "true" postglenoid process has already

been noted above in describing the lateral view of the temporal bone. Black referring to Skull III remarks as follows: "Medially the articular portion of the fossa is limited by the almost vertical temporal wall which in turn passes in smoothly rounded contour on to the inferior surface of the bone just lateral to the line of the sphenosquamous suture. There is thus no trace in this form of the development of a special limiting medial glenoid process like that so characteristic of the corresponding region in the great African and Oriental anthropoids." This description also applies to Skulls V, X, XI and XII. Black, however, overlooked one important peculiarity. There certainly is no high, compressed, crest-like process limiting the glenoid fossa as found in anthropoids, yet the formation of the medial wall is somewhat different from that in modern man. In the latter that wall usually is composed of two bony elements, an upper portion being formed by the squama of the temporal bone and a lower formed by the angular process of the sphenoid while the sphenosquamous suture marks the limit between the two bones. Cases in which the wall is only comprised of the squama may also be found in modern man but rarely and mostly confined to primitive races. In *Sinanthropus*, however, the medial wall is exclusively formed by the squama; the sphenosquamous suture runs medially to the wall along the even basal surface of the sphenoid.

As was mentioned above, the tympanic plate in all cases consists of only one element; it is not divided into an anterior and a posterior moiety by a transverse cleft along the floor of the meatus as is the case in Skull III. As in Skull III there are no traces of the styloid and vaginal processes. Further details will be found in the chapter dealing with the separate bones.

The occipital foramen is preserved only in Skulls XI and XII and solely with its posterior margin. Despite this incompleteness, it is possible to determine the position of the foramen or, more correctly, of the opisthion in its relation to the center of the cranial base. The first impression of the opisthion being located more to the rear than in modern skulls cannot be verified by exact measurements (see later). Although there is not direct indication as to the length and the width of the foramen, it can be inferred from the curvature of the preserved posterior arc that the foramen was relatively narrow. Furthermore, it is of interest to note that its rim is not flat but distinctly elevated.

In the Skulls XI and XII there is a broad and rather high ridge representing the lower extremity of an—otherwise not existing—median nuchal line which merges into the aforementioned rim. On either side, the ridge is bordered by a deep spherical depression which, so far as may be judged from the preserved parts, was also present in Skull X but only faintly developed in Skull III.

2. The Separate Cranial Bones

This chapter is devoted to the description of the individual bones which compose the *Sinanthropus* skull. Davidson Black already did so for Skull III. This task was rendered comparatively easy because that skull belonged to a juvenile and, thus, the bones were not yet fused within their sutures. The same holds good for Skull XII in which the individual bones were completely separated from one another when recovered.

It seems also most appropriate to include herein a detailed report on special features which thus far have only been mentioned briefly, and on the isolated fragments which, as shown above, represent Skulls I, IV, V, VI, VII, VIII and IX.

Frontal bone

The frontal bone of the *Sinanthropus* skulls as it appears in norma frontalis is illustrated in Figures 7 and 13 for Skull II; in Figures 51 and 57 for Skull X; in Figures 63 and 69 for Skull XI; in Figures 75 and 81 for Skull XII. The view of the bone in norma lateralis dextra is illustrated by Figures 6 and 12 for Skull II; by Figures 50 and 56 for Skull X; by Figures 62 and 68 for Skull XI; by Figures 74 and 80 for Skull XII. The view of the bone in norma lateralis sinistra is illustrated by Figures 5 and 11 for Skull II; by Figures 49 and 55 for Skull X; by Figures 61 and 67 for Skull XI; by Figures 73 and 79 for Skull XII. The view of the frontal bone in norma verticalis is illustrated by Figures 9 and 15 for Skull II; by Figures 53 and 59 for Skull X; by Figures 65 and 71 for Skull XI; by Figures 77 and 83 for Skull XII. The view of the bone in norma basalis is illustrated by Figures 10 and 16 for Skull II; by Figures 54 and 60 for Skull X; by Figures 66 and 72 for Skull XI; by Figures 78 and 84 for Skull XII.

Isolated frontal bones belonging to Skull I are given in Figures 2, 3 and 4; those belonging to Skull VI in Figures 31 and 34; those belonging to Skull VIII in Figures 46, 47 and 48. The isolated frontal bone of Skull XII is illustrated in Figures 90, 91 and 92. For the isolated frontal bone of Skull III cf. Davidson Black's publication (1931) Plate I, Figures 1 and 2.

When the isolated frontal bone is viewed from in front (Fig. 90) the extraordinary breadth and heaviness of its supraorbital and glabellar regions, the deep and narrow notch which separates them from the squama and represents the postorbital constriction, and the relative narrowness of the squama itself become much more striking than is true of the frontal view of the skull as a whole. The same applies to the supratoral sulcus the distinctness of which accentuates the bulkiness of the supraorbitals. The sulcus is pronounced particularly within the supraorbital region proper where the thickness of the supraorbitals is greatest. The supraorbitals of either side are united by a "torus glabellaris" which rises above the nasal bridge. This torus appears considerably depressed when compared with the supraorbital tori proper and the sulcus separating the former from the squama, consequently, represents only a slightly concaved slope coursing down from the frontal tuberosity toward the glabella. Yet there is a distinct edge where this slope declines toward the frontal surface of the torus; this edge continues toward the supraorbitals on either side and gradually fades out.

The two supraorbitals are rather thick and far projecting prominences (cf. Tables II and III). Their sagittal length above the middle of the orbit—the point where the frontal tuberosity rises above the supratoral sulcus taken as its approximate posterior extremity—measures as an average 19.2 mm. (cf. Table II, A). The torus glabellaris either projects to the same extent as the supraorbital tori or even somewhat more. The thickness of the latter varies with reference to the location of its maximum. When Skull III is omitted because of its juvenile character, the average thickness is 15.4 mm. (cf. Table II, B). In some cases the middle portion of the margin is the thickest, in others the medial one (cf. Table II). But in all cases the supraorbitals decease in thickness rather abruptly toward the zygomatic process. The margin and the anterior surface of the supraorbitals are remarkable by a distinct depression involving the entire medial portion. The depression seems to be more accentuated by the existence of a rather strong tubercle ("processus supraorbitalis") marking its lateral extremity. Both pecularities are well developed in Skulls X (right side, Fig. 57, pso) and Skull XII (both sides, Fig. 81, pso). The depression obviously corresponds to the "incisura supraorbitalis" of modern man, while the tubercle apparently is homologous to the slight thickening of the supraorbital margin lateral to the incisure and always present when the latter is wide enough. The "foramen" supraorbitale is missing in the *Sinanthropus* Skull.

In describing the norma basalis view attention has already been drawn to the flatness of the entire orbital roof. This flatness also involves the orbital surface of the zygomatic process

TABLE II

A. *Length of the Frontal Tori (measured in mm. above the mid-line of the orbital roof)*

Sinanthropus II		Sinanthropus III		Sinanthropus X		Sinanthropus XI		Sinanthropus XII	
l	17	l, r	18	r	22	l, r	18	l, r	21

B. *Thickness of the Frontal Tori (measured in mm. near the anterior margin)*

	Sinanthropus II	Sinanthropus III		Sinanthropus X		Sinanthropus XI		Sinanthropus XII	
	l	r	l	r	l	r	l	r	l
Medial	19.6	12.0	12.8	14.0	13.0	13.0	—	16.0	16.2
Middle	17.4	11.5	12.7	16.5	—	13.2	13.8	14.6	15.6 ?
Lateral	11.2	10.8 ?	12.0	12.0	—	—	—	14.0	14.5 ?

which in modern man displays a rather distinct depression lodging the lacrimal gland. Davidson Black emphasized its presence in Skull III which, indeed, shows a rather deep lacrimal groove on either side. It is all the more surprising that such a groove is completely absent in Skulls II, X, XI and XII. In Skull XII, particularly on the left side, there is a distinct depression corresponding in size and form to a lacrimal groove in modern man, but in *Sinanthropus* it is located much further backward, namely above the sphenoorbital suture. A similar depression at exactly the same place may be found in female orang-utang and in male and female chimpanzee and gorilla while there is no lacrimal groove in the typical human place. In studying this question I arrived at the conclusion that the groove-like depressions in the lateral part of the orbital roof in reality do not have any causal relation to the lacrimal gland. In chimpanzee, for instance, where I was able to make a thorough dissection of the region in question the lacrimal gland occupied the same place as in man without causing a depression in the orbital roof, while the above mentioned posterior depression lodges a particular accumulation of fat belonging to the layers of adipose tissue which fill the orbit. As the groove is developed in the infantile Skull III where the orbital roof, as a whole, is much more vaulted than in the adult skulls, I consider the groove as an infantile formation which disappears during growth. This view is confirmed by the fact that in all infantile skulls of anthropoids a distinct groove exists and that in infantile and fetal skulls of modern man the groove is much more pronounced than in adults. In the *Homo modjokertensis* skull which represents a baby *Pithecanthropus* a distinct groove is recognizable while it is absent in the adult *Pithecanthropus* Skull II.

The optic canal or, more correctly, its upper and lateral walls are preserved in almost its entire length in Skull XII (right side, Fig. 84, fop). The length of the preserved part measures 10.5 mm. and the horizontal diameter of the orbital orifice 5.5 mm. The direction of the axis aims almost laterally toward the zygomaticofrontal suture; with the median sagittal plane the axis forms an angle of 48°; the distance between the medial walls of the two orbital orifices is 29.5 mm. In modern man the three measures, according to the figures supplied by St. Oppenheim, are as follows: length of the canal 4–9 mm.; horizontal diameter of the orbital orifice 5.7–5.8 mm. (diagonal diameter varying in different races from 3.07 to 5.17 mm.); axis angle 38.3°. The difference in axis angle between *Sinanthropus* and modern man apparently is due to the greater interorbital breadth of the *Sinanthropus* skull (see later).

In Skull XII the ethmoidal bone is broken off along the two frontoethmoidal sutures so that the ethmoidal notch and the ethmoidal sinuses within the bordering margins are exposed. Almost the same conditions exist in Skulls III and XI with the only difference that in these cases but one bordering margin of the ethmoidal notch is preserved. The width of the middle of the notch itself is 19 mm. and the least interorbital breadth, measured just in front of the orbital orifice of the optic canal, 29 mm. Both measurements are considerably in excess of corresponding ones of modern man, but no actual figures are available for comparison.

The nasal part of the frontal bone is more or less preserved in Skulls II, III, X, XI and XII, and, in addition, in Skulls II and XII the greater part of the nasal bones are attached to the frontal bone. Viewed from below, all of the above mentioned skulls, with the exception of Skulls III and X, display a sharp median crest apparently representing the frontal spine.

In Skull II there is a small smooth cavity above the posterior extremity of the spine, and between this end and the origin of the crista galli (Fig. 16, sf). This cavity of a width of 7 mm. and a depth of 5 mm. represents the frontal sinus. Except for this cavity, the entire interorbital portion and the supraorbitals are solid. In Skull X only the upper parts of the interorbital portion are preserved with a small sinus on the right side of the portion (Fig. 60, sf); the supraorbitals are solid also in this specimen. Conditions in Skull XI are similar to those of Skull II; on either side of the interorbital portion there is a small sinus (Fig. 72, sf) while the supraorbitals are solid. The same is true of Skull XII; there is a small sinus within the midline and a larger one on the right side, but the position of the latter indicates that it must be rather considered as an enlarged ethmoidal sinus (Fig. 84; ce, sf).

The frontal sinus in all of the four specimens are small and strictly confined to the lowest part of the interorbital region. They neither extend upwards nor forwards to the glabellar region nor laterally into the supraorbitals proper or the roof of the orbits. In reality, they thus represent the cellulae frontales of the ethmoidal bone while true frontal sinuses are missing. Contrary to this condition, there is a rather large frontal sinus on either side of Skull III as described by Davidson Black and illustrated by a skiagram on Plate XI, Fig. 3, of his paper (1931) and Fig. 228 D of this paper. Nevertheless, in this specimen also the sinuses do not trespass the boundary of the interorbital region and scarcely extend over the roof of the orbit, neither do they reach up to the glabellar region.

The *Sinanthropus* skull differs in this feature from that of *Pithecanthropus* as well as from the Ngandong skulls. In *Pithecanthropus* Skull I (Dubois)—the region in question is not preserved in Skulls II, III and IV—there is a large sinus extending upwards to the glabella and laterally over the medial part of the orbital roof and the same is true of the Ngandong skulls. In modern man both occurrence and size of the frontal sinus show a great variability; however, it is noteworthy that in primitive races, as for instance in the Australian aborigines, the sinus is relatively small and not infrequently missing completely, despite the rather common development of a torus-like superciliary ridge.

The external surface of the squama of the frontal bone is characterized by several particular features. As already noted above, it is separated from the supraorbitals by a broad and distinct furrow, the supratoral sulcus. The central part of the lower half of the squama bulges not unlike the frontal bump of recent Negro skulls, while the upper half shows a slight keel-like median ridge with a flattened area on either side. A specific feature is the squamous character of the entire temporal section of the coronal suture and its continuation, the sphenofrontal suture. In all of the specimens in which these parts are preserved and exposed, the margin of the

frontal bone is levelled with the suture surface facing directly lateralwards to a maximum extent of 13 mm. in longitudinal direction. The surface of the sphenofrontal suture in which the coronal suture continues looks downwards; its maximum extent in longitudinal direction is 23 mm. The sphenoidal angle of the parietal bone and the greater wing of the sphenoidal bone overlap the frontal bone; as is the case in the squamous suture, the squama of the temporal bone rests on the parietal bone. In recent man the temporal section of the coronal suture and the sphenofrontal suture also possess a squamous character but in no instance does the overlapping reach such proportions as in *Sinanthropus*, a difference certainly due to the greater thickness of his cranial bones.

In Skull XI the frontal bone is divided in its entire length by a frontal suture; it runs along the sagittal ridge and, crossing the glabellar torus, extends downwards to the nasofrontal suture. The bregmatic section of the suture is completely fused to an extent of 16 mm. and shows the typical zigzag-pattern of other cranial sutures. The remaining part has a slightly undulatory character in the upper half but a linear in the lower half. The character of the supranasal section cannot be ascertained as the entire suture region is broken off. This is the first case in which persistence of a metopic suture in a fossil hominid is recorded; it is all the more remarkable as Skull XI belongs to an adult individual of advanced age as shown by the complete fusion of the parietal suture and major parts of the lambdoid and coronal sutures. The general significance of such an occurrence has been discussed in a recently published paper by the present author (1941b) to which the reader is referred.

The interior of the frontal bone (Fig. 92) shows some characteristic differences when compared with that of recent man. In regard to the general shape and relation between squama and floor the squama forms an angle of about 50° with the floor, while in modern man this angle is a right one. In modern man the floor of the fossa declines gradually from lateral to the lamina cribrosa whereas in *Sinanthropus* the floor generally is even and slopes rather abruptly toward the lamina or, more correctly, toward the ethmoidal incisure, as the lamina with the entire ethmoidal bone is broken off. The most interesting difference, however, concerns the region of the foramen caecum. The crista galli is missing in all of the specimens but the entire crista frontalis (cf) from the point of its origin up to where it fades out is preserved in the form of a thin, but high blade-like elevation. In modern man the crista commences immediately above the foramen arising directly from the plain surface of the squama and courses upwards perpendicularly. In *Sinanthropus*, however, the whole surface on either side of the origin of the crista is caved and courses downwards considerably, and at the same time slightly backwards. The place where the foramen caecum is expected to be found thus lies more than 15 mm. below the level of the floor of the fossa whereas in recent man it is at the same level or only slightly below. Whether a foramen caecum occurred in *Sinanthropus* is difficult to determine. In Skulls II and III the bone is broken off just at the origin of the crista frontalis while in Skull XI it is preserved for a distance of about 5 mm. from this origin, but there is no indication of the foramen. This in turn suggests that it may be absent in *Sinanthropus* as is true in anthropoids. On the other hand, the existence of a well pronounced crista frontalis is a distinct human characteristic, for this formation is missing in anthropoids or, if present, it is represented only by a low, insignificant ridge. The crista frontalis fades away at approximately the superior end of the lower third of the height of the squama. Only in Skull III does it divide into two low legs within this level which enclose a sagittal sulcus. No such sulcus is to be found within the frontal portion of the vault in any of the other cases.

The eminences and depressions for the convolution of the frontal lobe of the brain are very much marked, particularly at the orbital planum, but they also extend upwards to the sides and the roof.   G. Schwalbe (1902, 1907) called attention to the fact that such an endocranial relief usually did not cover more than one third of the squama in modern man.   In all of the *Sinanthropus* specimens it extends to a much higher level, but it vanishes rather abruptly short of the coronal suture.   This stop coincides with a thickening of the bone so that the passage leading from the carved to the plain surface seems to be marked by a threshold-like boundary— limen coronale (Figs. 16 and 92; lid).   The degree of the development of this demarcating line varies considerably; it is most pronounced in Skull II and least in Skull X.   True Pacchionian pits have not been found in any of the available frontal bones.

A description of the pattern of the endocranial relief cannot be given herein.   It will form the subject of a separate study dealing with the endocranial cavity of the *Sinanthropus* skull.

Parietal bone

The parietal bones as they appear in lateral views of left and right sides of *Sinanthropus* skulls are shown in Figs. 5, 6, 11 and 12 for Skull II; in Figs. 49, 50, 55 and 56 for Skull X; in Figs. 61, 62, 68 and 69 for Skull XI; in Figs. 73, 74, 79 and 80 for Skull XII.   The aspect of the vertical view is illustrated in Figs. 9 and 15 for Skull II; in Figs. 53 and 59 for Skull X; in Figs. 65 and 71 for Skull XI; in Figs. 77 and 83 for Skull XII.

Isolated parietal bones are illustrated in Fig. 1 for Skull I; in Figs. 17, 18, 19 and 20 for Skull IV; in Figs. 22 and 27 for Skull V; in Figs. 32 and 35 for Skull VI; in Figs. 37 38, 39 and 40 for Skull VII; in Figs. 93, 94, 95, 96 and 97 for Skull XII.

There are four major different features that characterize the parietal bones of *Sinanthropus* when compared with modern man: they appear (1) smaller, (2) flatter, (3) thicker and (4) more rectangular in their outlines than is true of the average of parietal bones of modern man.

TABLE III

Length of Chords and Arcs of the Margins of the Parietal Bones of Sinanthropus

	Margo Sag.		Margo Coronal.				Marg. Lambd.				Marg. Temp.			
	Chord	Arc	Chord		Arc		Chord		Arc		Chord		Arc	
	r	l	r	l	r	l	r	l	r	l	r	l	r	l
Skull II	99	105	—	90(?)	—	97(?)	80	82	96	92	—	87	—	92
Skull III	94	99	79	87	111	106	86	81	95	94	98	91	100	93
Skull X	106	113	—	—	—	—	87	82	98	90	—	—	—	—
Skull XI	86	92	82	86	101	102	81	80	95	103	87	93	96	94
Skull XII	91	95	93	90	105	102	86	90	93	102	98	99	102	106
Average	95.2	101	86.7		103.4		83.5		95.8		93.3		97.6	

Table III gives the length of the chords and arcs of the 7 parietal bones of *Sinanthropus* suitable for these measurements.   In Skulls III and XII the measurements were taken from the separate bones, while in the remaining ones they were taken on the skulls themselves.   Only a limited number of figures referring to the arc length are available of modern man and these are given in R. Martin's textbook (1928).   The arc lengths of average parietal bones of different races of modern mankind (dolichocephalic and brachycephalic) of males and females, according to Martin, are as follows: 124.8 mm. for the sagittal margin, 110.4 mm. for the coronal margin, 94.0 mm. for

the lambdoid margin and 98.6 mm. for the temporal margin. As to other hominids, I found only one reference to the Neanderthal skull in Schwalbe's paper (1901) but his figures—without any further explanation: 101 mm. for the sagittal margin, 89 mm. for the coronal margin and 73 mm. for the lambdoid margin—evidently are much too small to represent average measurements. In any case, the parietal bones of *Sinanthropus* are smaller than those of modern man, particularly in sagittal and coronal directions. The differences in coronal extension can best be illustrated (Fig. 98) by superimposing the outlines of the coronal (a) and lambdoid (b) margins of *Sinanthropus* (heavy line) on those of modern man (dotted line) with the sagittal sutures serving as lines of orientation in both cases. As the figure shows, the parietal bone of *Sinanthropus* is considerably shorter than that of modern man. If the area occupied by the external surface of the bone is calculated in square centimeters, that of *Sinanthropus* would be about 65 and that of modern man (the parietal bone of a modern European male individual taken as an example) about 104 or, in other words, the *Sinanthropus* area covers only about 63 per cent of that of modern man.

The greater flatness of the parietal bone of *Sinanthropus* seems to be a striking feature. However, when submitted to a more careful examination, it becomes apparent that the differences are much smaller than was first supposed. It is considered a reliable method to determine the degree of curvature of the parietal bone as a whole by computing the index between the length of the chord and that of the arc of its four margins: the higher the index, the flatter the bone and conversely. The indices thus derived for *Sinanthropus* are recorded in Table IV,

TABLE IV

Chord-Arc Indices of the Parietal Bone of Sinanthropus and Modern Man (average figures)

	Margo Sagitt.	Margo Coron.	Margo Lambd.	Margo Temp.
Sinanthropus	94.3	83.8	87.3	95.6
Recent man ♂ + ♀	89.7	84.9	89.9	93.4

using as basis the figures of chords and arcs listed in Table III, to which averages obtained for recent man have been added in computing R. Martin's (1928) list of chord-arc indices of some dolicho- and brachycephalic races of modern mankind. As may be gathered from these figures, only the longitudinal (sagittal and temporal) margins of the *Sinanthropus* bone are less curved than those of modern man while conversely the transverse (coronal and lambdoid) margins are more so. This can also be easily demonstrated by superimposing the margins concerned as illustrated in Figure 98. That the coronal curvature is more pronounced in *Sinanthropus* than in modern man, as especially evident on the internal surface of the bone, is due to the extraordinary thickness of the *Sinanthropus* parietal bone which will be discussed later together with the architectonic structure of the entire skull.

As to the shape of the *Sinanthropus* parietal, it is obviously more rectangular than that of modern man, apparently owing to differences in the course of the coronal and lambdoid margins and, consequently, also to those in the form of the sphenoid and mastoid angles. In *Sinanthropus* both margins run from the sagittal suture within a rather strict frontal plane toward the temporal margin with no tendency to deviate in anterior direction so characteristic of modern man. In addition, the temporal margin forms almost a straight line and not a curve with upward directed convexity as is the rule in modern man. The differences in size and shape of the parietal

bones are, of course, only an expression of the smaller total size and the divergent form of the *Sinanthropus* calvaria.

The sutures of the separate bone do not show significant differences with regard to the appearance of their single sections; on the whole, they are like those of modern man. But they do differ in size and form of the denticulations. While these structures generally are narrow and long, terminating mostly in acute points, in *Sinanthropus* they are shorter, broader and more blunt and more often show rather the character of crests than of points. This special feature may be connected with the thickness of the bone; nevertheless, it is peculiar to *Sinanthropus* where it is found not only in the juvenile Skull III but also in like degree of development in the more mature Skull XII. The greater thickness of the *Sinanthropus* parietal apparently is also the cause for the free border of the temporal margin being much less edged than in modern man and for the relatively smaller area occupied by the squamous suture. On the other hand, the fine linear cuts of varying lengths which radiate from the superior demarcating line of the area of the squamous suture along the whole temporal depression are present in all of the *Sinanthropus* parietal bones. Like in modern man, their formation is brought about by the embedding of thin bundles of tendon fibers of the temporal muscle within the superficial bony substance.

The essential peculiarities of the external surface of the parietal bone which consist of: the parietal tuberosity, the occurrence of the parietal foramen, the course of the temporal line and the development of a torus angularis, have already been discussed above in connection with the description of the norma lateralis and thus do not merit any further mention. The torus angularis, however, is a structure involving not only the external aspect of the mastoid angle but also affects the entire bone in so far as to cause the inside of the angle to project, thereby determining the course of the inner contour such as illustrated in Figure 98 b (am). As to the outer surface of the sphenoid angle, in no instance is there a distinct depression corresponding to the "sulcus sphenoparietalis" as described by Schwalbe (1907) in modern man.

The general depression which characterizes the obelion region and is most pronounced in Skull XI is clearer in the skull than in the separate parietal bones. However, there occurs a special, more localized depression in this region which has already been noted by Black (1931) in his description of Skull III. This depression occupies the posterior end of the sagittal region on each side of the suture beginning 26 mm. in front of the lambda and extending backwards down to this landmark. It is deepest and broadest in its anterior part and gradually becomes shallower and narrower. The parietal foramen only recognizable on the right bone is near the anterior and medial extremity of the depression. None of the other *Sinanthropus* parietal bones show this peculiarity. But such a depression in exactly the same place (Fig. 247) is found in *Pithecanthropus* III (cf. von Koenigswald and Weidenreich, 1938). The two formations differ only in so far that in the latter case the suture rises to a low crest thus dividing the depression into a left and right one while in *Sinanthropus* the suture runs through the depressed area.

Depressions within the obelion region of skulls of modern man have been reported by several authors. They were recorded as "depressio praelambdoidea" or "fovea verticalis" or " trigonum supralambdoideum," but none of these formations answers completely to that of *Sinanthropus*. Le Double (1903) is inclined to regard them as results of disturbances in the ossification of the parietal bone. In how far such an interpretation may be valid for modern man I am unable to conclude, but I doubt that it may be applied correctly to *Sinanthropus* and *Pithecanthropus* for in these cases the depression is distinctly a superficial one, the bone as a whole being even thicker here than within the sagittal region in front thereof. Yet it is noteworthy that

both skulls which exhibit this feature are those of infantile individuals. Therefore its occurrence may have something to do with the ontogenetic development of the skulls.

The internal surface of the parietal bone is characterized by the formation of a particular relief consisting of "impressiones digitatae" and "juga cerebralia" which correspond to the convolutions and fissures of the brain only to a certain extent. In addition, there exists a special system of linear grooves brought about by ramifications of the meningeal vessels. Since I have devoted a special study to these grooves (1938b), I may omit them herein, epsecially so, because no new observations on this subject have become available since.

The impressions and juga differ remarkably from those of the frontal bone described above in being much larger and flatter and much less distinct than the latter. Therefore, they do not merit the terms "impressiones digitatae" and "juga" although they do reflect the unevenness of the surface of the brain and its wrapping-in membranes. In almost all of the parietal bones there is a distinct ridge that runs parallel to the sagittal margin and rather close to it. It is restricted to the posterior two third of that margin and flattens toward the lambdoid margin. Between the ridge and the margin proper there is a shallow furrow. This formation corresponds to the sulcus sagittalis in modern man. Furthermore, in some cases, there are close to the sagittal margin typical foveolae granulares; very characteristic ones occur in the right parietal bones of Skulls IV and XII and in the left bones of Skulls III and X. In all of the cases they are located within the anterior part of the bone and within a distance between approximately 10 to 25 mm. from the sagittal margin. Le Double (1903) found the foveolae granulares in modern man located most frequently near the frontal angle and usually at a distance of 25 mm. from the coronal suture and 15 mm. from the sagittal suture. An interior opening of the parietal foramen is recognizable only on the right bone of Skull III.

The interior surface of the sphenoid angle is characterized by the development of a high and broad crest which, when preserved in its entirety as in the left bones of Skulls III and XII, rises to a pyramid-like spur the tip of which marks the margin of the sphenoid angle (Figs. 27, 96, 98; cs). This formation is nothing more than a continuation of the edge of the lesser wing of the sphenoid which forms the boundary between the floor of the anterior cerebral fossa and the trough-like lateral section of the middle cerebral fossa. The extension of the crest toward the center of the parietal bone makes the inferior portion of that bone a part of the fossa cerebralis. The crest courses in the direction of the inferior moiety of the lambdoid suture but rapidly decreases in development with the result that it is almost completely levelled before it reaches the midline of the bone. In all of the cases the spur is pierced by the beginning of the ramus anterior of the middle meningeal vessel.

Schwalbe (1901, 1907) was the first to note the presence of such a formation in modern man. He observed a low ridge, which he named "crista Sylvii," in over 60 per cent of the examined parietal bones. From his illustration (Fig. 2, 1907) of the most pronounced case he met it can be deduced that this structure is only a faint copy of what is found in *Sinanthropus*. Schwalbe, furthermore, made the statement that such a crest is completely absent in anthropoids and all the *Catarrhinae*, though faintly developed in *Cebus*. From those observations he concluded that the crest must be considered a progressive human character. In my paper on the role of the brain in the phylogenetic transformation of the human skull (1941b) I showed how cautious one must be before drawing any such conclusions. The crista Sylvii serves as another example. It is only partly true that the crest is missing in anthropoids—it is a rather constant occurrence in orang-utang—but it is almost incomparably more developed in *Sinan-*

thropus than in the great apes and, as I have also been able to ascertain, in the Gibraltar Skull. Thus, it cannot be considered a progressive human character but rather a regressive one.

McCown and Keith (1939) found a well developed "Sylvian buttress," as they call the formation, in the Skull of Skhūl V of the Mt. Carmel population. According to those authors, the buttress has a width of 15 mm. at its base and a height of 55 mm.; they add: "Whereas in modern skulls, although it may be 7 mm. or more in height, it is usually narrow based and sharp-edged even in the most primitive races." I doubt the correctness of this observation as far as modern man is concerned. Neither Schwalbe nor I have been able to find these high developed cristae. If the measurement of the height is taken on the entire skulls, it is impossible in most cases to determine the exact boundary between the extremity of the lesser wing of the sphenoid and the parietal bone proper. The former, of course, projects much more than the latter. Its special development is apparently related to the trough-like shaping of the lateral section of the middle cerebral fossa that lodges the temporal lobe of the brain. I will return to the whole question later. Schwalbe seeing a direct connection between the Sylvian crest and the depression on the outisde of the parietal bone uses the latter as an indicator for the exact localization of the Sylvian fossa of the brain. Of course, there is no doubt that the crest fits into the deep fissure between the temporal and frontal lobes which in *Sinanthropus* is much more of a gap than in modern man, but there is no sign of a corresponding depression on the outside of the *Sinanthropus* skull.

A second characteristic feature of the inside of the parietal bone is the inward bending of the mastoid angle caused by the presence of a torus angularis, that is to say, by the thickening of the bone (Fig. 98). In modern man this region is usually thinner than the surrounding parts on account of the transverse sinus which forms here a deep sulcus by crossing the corner to a greater or smaller extent. In *Sinanthropus* the transverse sulcus never extends as far upwards as to reach the parietal bone but rather remains restricted to the occipital bone and the mastoid portion of the temporal bone as is always the case in anthropoids. The same arrangement as in *Sinanthropus* may occasionally be found in modern man; then the inner surface of the mastoid angle is bent inwards and the bone correspondingly thicker at this part, but the conditions of *Sinanthropus* will never be attained.

I do not wish to enter into a discussion of the particular relief of the inside of the parietal bone, reserving it for a special paper dealing with the endocasts of *Sinanthropus*. Only one particularity must be mentioned here. In numerous textbooks on human anatomy there is recorded that the thickness of the parietal bone is most pronounced in the center in correspondence to the parietal tuberosity. Schwalbe (1902) refuted this claim, referring in particular to English and French authors. According to their statements which Schwalbe confirmed, there usually is a distinct depression on the inner surface of the center and the bone thus thinner than in the surrounding parts. Be it as it may, in *Sinanthropus* (Fig. 237) the center certainly is not the thinnest part of the bone, neither is there a special depression corresponding to the location of the parietal tuberosity.

Occipital bone

The occipital bone as it appears in the occipital view of the entire skull is illustrated in Figs. 52 and 58 for Skull X; Figs. 64 and 70 for Skull XI; Figs. 76 and 82 for Skull XII. In lateral views in Figs. 49, 50, 55 and 56 for Skull X; in Figs. 61, 62, 67 and 68 for Skull XI; in Figs. 73, 79 and 80 for Skull XII; in basal view in Figs. 54 and 60 for Skull X; in Figs. 66 and 72 for Skull XI; in Figs. 78 and 84 for Skull XII.

Separate occipital bones or parts thereof are illustrated in Figs. 21, 22, 23, 25 and 27 for Skull V; in Figs. 41, 42, 43 and 44 for Skull VIII; in Figs. 99 and 100 for Skull XII.

Inside views of the occipital bone of Skulls III and XII are also given in Fig. 234 A and B, respectively.

As neither the basal nor the condylar portions of the occipital bone are preserved in any of the skulls and skull fragments, the description of the bone is restricted to the squama.

The general form of the squama is defined by the relation between the greatest breadth which coincides nearly with the asterionic breadth and the lambda-opisthion length recorded in Table V. The average index for *Sinanthropus* is 74 for the chord and 75.6 for the arc. Ac-

TABLE V

Length-Breadth Measurements and Indices of the Occipital Squama of Sinanthropus

	Skull III		Skull XI		Skull XII		Average	
	Chord	Arc	Chord	Arc	Chord	Arc	Chord	Arc
Length	84 (?)	106 (?)	86	117	86	118	85	114
Breadth	117	145	113 (?)	153	115	155	115	151
Index	71.7	73.2	76.1	76.6	74.8	76.2	74	75.6

cording to Martin's (1928) list this chord index ranges from 81.9 (brachycephalic type) to 98.0 (dolichocephalic type) with an average of 87.3 within various races of modern mankind. In other words, the squama of the *Sinanthropus* occipital bone is very short and thus falls far below the average of modern mankind. Such poor development of the squama in longitudinal direction, characteristic also for anthropoids, seems to be due to an under-development of the upper scale if the mid-sagittal extensions as they appear in posterior aspects serve as basis for comparison. The index of the midsagittal chords of the upper and lower scales of *Sinanthropus* and the basic measurements are listed in Table VI. From these figures it may be gathered,

TABLE VI

Length of the Mid-Sagittal Chords and Chord-Index of the Upper and Lower Scales of the Occipital Bone of Sinanthropus

	Skull III	Skull X	Skull XI	Skull XII
Upper scale	46	48	45	56
Lower scale	57 (?)	—	65	56
Index	124	—	144	100

that the upper scale is shorter than the lower scale or equal to it, the index of the three specimens available for these measurements ranging from 100 to 144 (average: 123). Exactly the reverse conditions exist in modern man. In almost all of the cases the upper scale is longer than the lower. According to R. Martin's (1928) list the average of the chord indices ranges from 52.4 to 71.2 with a total average of 62.3. In other words, when the mid-sagittal chord of the upper scale is 100 mm., the length of the lower scale is 123 in *Sinanthropus* but only 62 in modern man.

The difference partly depends on the total length of the occipital bone—in *Sinanthropus* the lambda-opisthion chord is shorter than in modern man (*Sinanthropus* average: 85; modern man average: 94.8, according to R. Martin's list)—but chiefly on the position of the boundary

between the upper and lower scales, which is determined by the level of the occipital torus and that of the superior nuchal line, respectively. In *Sinanthropus* the boundary is marked by a very pronounced torus occipitalis. The torus is demarcated from the occipital plane in its entire length by a distinct furrow, the sulcus supratoralis. If this sulcus is taken for the inferior boundary of the occipital plane or the upper scale, the latter forms a low triangle with a very long base. The average length of this base is 110 mm. for the four *Sinanthropus* specimens (Skulls III, X, XI and XII) in which this measurement can be defined correctly, and the average height of the triangle is in the same cases 38.6 mm. The average breadth-height index of the upper scale, therefore, is 35.1. In modern man the index ranges between approximately 40 and 80.

The curvature of the *Sinanthropus* squama is rather pronounced, mainly due to a sharper flexion of the lower scale. The average sagittal occipital index (curvature index) as expressed by the ratio of lambda-opisthion chord and lambda-opisthion arch gives a good idea of the degree of the curvature; it is 72.1 (cf. Table VII). In modern man the average lambda-opisthion

TABLE VII

Occipital Curvature Index—Ratio of Lambda-Opisthion Chord and Lambda-Opisthion Arc—of Sinanthropus

	Skull III	Skull XI	Skull XII
Chord Arc	84 108	86 117	86 118
Index	77.8	73.5	72.9

chord of all the races totals 94.8 mm. and the arc 116.3 mm.; the curvature index thus is 82.8 (measurements according to R. Martin's list). The difference between the two indices (*Sinanthropus* and modern man) consists of 10 units or, in other words, the squama is much more curved in *Sinanthropus* than in modern man. The significant difference expressed by this index, however, is but partly caused by the curvature of the squama as a whole. The predominance in length of the arc over the chord in *Sinanthropus* is chiefly due to the development of the occipital torus, the special appearance of which has already been described above (see norma occipitalis).

The linea nuchae superior which demarcates the nuchal plane from the torus bends downwards near the lateral margin of the bone and thus also forms the lateral boundary of the plane. Finally, the line merges into a crest which runs along the occipitomastoid suture (occipitomastoid crest; cf. Weidenreich, 1940b). The nuchal plane as a whole either possesses a convex and rough surface without showing much of a particular relief (like in Skulls III and XI) or it displays some characteristic peculiarities like in Skull XII. In this specimen the nuchal plane shows distinct depressions on either side below the torus separated from each other by the external occipital crest. Below each depression there is an oval-shaped elevation very distinct as a whole but rather obscure in its boundaries. The elevation, or at least its superior portion, corresponds to the linea nuchae inferior of modern man. Above the occipital foramen the planum displays a round pit on either side of the midline so that the latter assumes the character of a median crest. In reality, however, neither this nor the superior crest that separates the two aforementioned depressions can be strictly considered as an elevation above the planum level but rather as the remaining non-depressed planum surface. An external occipital protuberance and a real median occipital crest, both of which occur rather frequently in modern

man, are not developed in *Sinanthropus.* The margin of the occipital foramen preserved only in its posterior part differs from that of modern man mainly in being thicker and less edged.

The character of the lambdoid and occipitomastoid sutures has already been described above. Also noted there was the persistence of the sutura mendosa and the tendency of keeping the upper scale or its apical portion more or less separated from the rest of the squama by accessorial transverse sutures such as indicated in Skulls II, X, XI and XII.

The fragment of the occipital bone of the infantile Skull VIII deserves special note (cf. Figs. 41, 43, 45). It shows the central portion of the torus already as a well developed general swelling that marks the angle between the upper and lower scale. Although the supratoral sulcus is but faintly indicated and the nuchal inferior line completely missing, there is already a pronounced superior depression on either side and a median crest.

The internal surface of the squama (Figs. 100 and 234) reveals the familiar picture of the superior and inferior occipital fossae of either side, separated from each other by a well developed eminentia cruciata with an internal occipital protuberance in its center. But there are some important differences when compared with modern man. The most striking diversity of the *Sinanthropus* bone concerns the inequality in size of the fossae cerebrales and cerebellares. In modern man the cerebellar fossae are distinctly larger than the cerebral ones in both longitudinal and transverse directions. Unfortunately, no exact figures are obtainable from the literature but from a rough estimate it seems that the area of the cerebellar fossae compared with that of the cerebral would be a little more than four stands to three. In *Sinanthropus* the relationship is inverted; the area of the cerebellar fossae is much smaller than that of the cerebral ones, namely almost the half of the latter. In accordance therewith the transverse arms of the eminentia cruciata and the protuberance itself are much closer to the occipital foramen than is true in modern man.

Although similar differences occur in the Neanderthal skulls, they have as yet completely escaped observation. The only fact recorded in the majority of publications dealing with fossil hominids is the difference in the position of the internal protuberance in its relation to the external one. In modern man the external protuberance is situated within the same level as the internal or even lower while in Neanderthal man the conditions are reversed. In my paper on the torus occipitalis (1940b) I already called attention to the great vertical distance between the "inion," representing the center of the occipital torus, and the internal protuberance, a peculiarity which is characteristic of all the *Sinanthropus* occipital bones. Table VIII is taken from that publication. The figures merely reveal how much lower (closer to the opisthion) the internal protuberance is situated than the inion when *Sinanthropus* is compared with the Neanderthalians. The greater the distance, the more the internal protuberance approaches the occipital foramen and the farther it is from the external protuberance.

There are two reasons for this reversion of the mutual position in *Sinanthropus* and modern man. The original conditions apparently are those found in *Sinanthropus* because of their being the same in anthropoids. In both cases a large nuchal and a small occipital plane is found to occur, for the basal portion of the squama that affords the attachment of the big cervical muscles is correspondingly spacious while the cranial portion that constitutes a part of the vault is relatively small. During the course of human evolution when the bulk of the cervical muscles decreased and the brain increased, the nuchal plane became smaller and the occipital plane larger or, in other words, the inion marking the boundary between the two planes shifts downwards closer to the occipital foramen. On the other hand, the change in position of the

TABLE VIII

Distance Between Inion (Center of the Occipital Torus) and Internal Protuberance in mm.

Specimen	Distance	Remarks
Sinanthropus Skull X	38.0	
Sinanthropus XII	35.0	
Sinanthropus XI	34.0	
Sinanthropus V	34.0 (?)	Next to the mid-line
Sinanthropus III	27.5	
Sinanthropus VIII (child)	17.0 (?)	
Pithecanthropus III	16.0	
Pithecanthropus II	15.0	
La Chapelle-aux-Saints	15.0	After Boule
Krapina	24.0	After Klaatsch
Spy II	20.0	After Klaatsch
Spy I	10.0	After Fraipont
Ehringsdorf	18.0	
Swanscombe	18.0	(Cast)
Piltdown	0.0	(Cast)

internal protuberance is caused by the expansion of the cerebellum which requires much greater space in modern man than in *Sinanthropus* (and anthropoids). Consequently, the transverse arms of the eminentia cruciata and the internal protuberance shift upwards, the fossae cerebellares thus occupying a larger area while the fossae cerebrales preserve their original size; in other words, the increase of the fossae cerebellares in modern man does not take place at the expense of the superior ones. In *Sinanthropus* the area occupied by the two cerebellar fossae is despite the smallness of the vault absolutely larger than in modern man, measuring up to 30 to 35 square centimeters while the cerebral fossae of the gorilla are of the same size as those of *Sinanthropus*. These conditions indicate that the occipital lobe does not participate in the general increase of the brain which mainly involves the vertex and obelion regions (cf. Weidenreich, 1936a).

The cruciate eminence of *Sinanthropus* (Skull XII) in principle shows the same arrangement as in modern man with the only difference that in accordance with the smallness of the area of the cerebellar fossae mentioned before an occipital internal crest is practically missing in *Sinanthropus*. The posterior extremity of the occipital foramen comes very close to the internal protuberance and, in addition, the elevated vertical portion separating the right and left cerebellar fossae is a broad and almost even swelling; it bifurcates almost immediately below the center of the eminence into two branches which flank the occipital foramen. In Skull III in which only the right upper portion of the internal crest is preserved the prominence in question was evidently higher than in Skull XII, but for the rest the formation apparently had been the same. The absence of an internal occipital crest and its substitution by a short and broad prominence is typical of anthropoids.

The sulcus sagittalis displays a great variability in breadth and depth. In Skulls III and XII it is represented by a broad and deep furrow, in Skull XI it is small and deep while in Skull X broad and shallow. The sulcus in no instance follows the midline but is situated more or less on the right side. In all of the six specimens available which permit conclusions in this respect the sulcus continues directly into the right transverse sulcus as is the rule in modern man

(Sturmhöfel according to R. Martin, 1928). However, in Skull III a well developed left sulcus is also present, although there are no connections whatever either with the right or the sagittal sulcus. In Skull XII the right transverse sulcus is shallow when compared with that of Skull III while the left represents merely a long and broad depression completely independent of that of the right side as well as of the sagittal sulcus. Similar conditions are found in the fragment of Skull V; here the entire central and right parts of the cruciate eminence are broken off with only the left side preserved. However, there is no indication of the presence of a sulcus but merely of a broad and blunt transverse ridge which separates the upper and lower fossae. The same conditions exist on the left side of Skulls X and XI with the transverse sulcus completely missing or, like in Skull XI, reduced to a short and shallow groove in the course of the ridge.

Like in modern man the posterior portion of the occipital foramen is flanked by a thickened and rounded margin which appears as a continuation of the inferior vertical arm of the cruciate eminence just described. In Skull XII, the only one in which this part is completely preserved, the two flanking branches are united with the eminence about 8 mm. beyond the posterior extremity of the foramen. They embrace a triangular pit the base of which is about 7 mm. long. Whether or not this depression is to be interpreted as a real fossula vermiana I do not venture to decide. Such a formation is very rare among anthropoids (Albrecht, 1884; Le Double, 1903) but occurs frequently in recent man, in certain races reaching up to more than 40 per cent (Australian aborigines 22 per cent; cf. R. Martin, 1928).

The relief of the fossae occipitales cerebrales bears a close resemblance to that of the internal surface of the parietal bones in so far as impressions and juga are but poorly developed. The conditions in this regard are the same as those in modern man. This is also true for the fossae occipitales cerebellares which are absolutely smooth.

In the small fragment of the infantile Skull VIII only the sagittal sulcus down to the center of the eminence and a part of the left cerebral fossa are preserved. The sulcus is broad and already rather pronounced. As was noted above, it continues directly into the right transverse sulcus. A well developed ridge that courses in oblique medial-lateral direction partitions the cerebral fossa into a smaller upper and a larger lower depression. There is, however, no analogous feature in any of the other adult specimens.

The relation between the outer and inner surfaces of the occipital bone is of some special interest. It does not seem questionable that in modern man the fossae cerebrales and particularly the fossae cerebellares cause convexity at the external surface which correspond in size, degree and position. This is certainly not the case in *Sinanthropus*. The site of the upper fossae is here occupied by the occipital torus which crosses the bone as a distinct super-structure and at no point is it concordant with the configuration of the inner side of the bone (cf. Weidenreich; 1940b). The fossae cerebellares are the reverse of the inferior parts of the elevation of the nuchal plane, described above as a special feature. But this exterior elevation extends much further upward beyond even the transverse sulcus, and thereby proves its absolute independence from the internal relief. In the fragment of the infantile Skull VIII the center of the superior fossa even corresponds to the crista occipitalis externa. These incongruities apparently are a consequence of the extraordinary thickness of the entire occipital bone. Since the reliefs of the outer and inner sides result from quite different shaping factors, it cannot be expected that one may act upon the other as long as the thickness of the bone is strong enough to preclude it. If, however, in the course of evolution, the bone becomes thinner and the modelling power of the cervical muscles weaker as is true in modern man, the expanding brain may exert

a greater influence upon the bone so that the outer relief will reflect the inner one to a certain extent.

Temporal bone

The temporal bones as they appear in lateral and basal views of the skulls are illustrated in Figures 5 and 11 for the fragment of the squama of the left side of Skull II; in Figures 21, 22, 25 and 27 for Skull V; in Figures 50, 54, 56 and 60 for Skull X; in Figures 61, 62, 66, 67, 68 and 72 for Skull XI; in Figures 73, 78, 79 and 84 for Skull XII.

Separate temporal bones or parts thereof and special views are illustrated in Figures 24, 26, 28, 29, 30 and 105 for Skull V; in Figures 33, 36 and 105 for Skull VI; in Figures 93, 94, 95, 111 and 112 for Skull XII; in Figures 101, 102, 103 and 104 for Skull III; in Figures 102, 103, 104 and 108 for Skull X; in Figures 109 and 110 for Skull XI.

Squamous portion

The *Sinanthropus* squama differs in form and proportions from that of modern man in a rather indicative manner. When typically developed and when the zygomatic process and its posterior continuation are taken as basis, the modern human squama rises considerably upwards with its parietal margin forming a high curve. The vertex of this curve varies in its position but is mostly found vertically above the mandibular fossa. The aspect of the squama is quite different in *Sinanthropus*. It looks more like a right angled triangle with the sphenoid margin forming the shorter cathetus, the parietal margin the longer one and the zygomatic process and its continuation, the supramastoid crest, the hypotenuse. The sphenoid angle is the right one. The most pronounced triangular form is shown by Skulls III (Figs. 101, 102), XI (Figs. 61, 67, 109) and XII (Figs. 73, 79) while in the remaining cases (Skull V) the squama approaches more the form of modern man with the parietal and sphenoidal margins losing their straight character and becoming slightly curved (Fig. 21). The triangular form of the squama is a typical simian character and very characteristic of anthropoids.

There is one other feature which is intimately correlated with the triangular form. In modern man, as just mentioned, the zygomatic process or, more correctly, the line along which the process is fixed at the squama and its posterior continuation course more or less parallel to the Frankfort plane whereas in *Sinanthropus* they form an acute angle of 30° with this plane. This peculiarity, too, is a simian character; in the male gorilla the line can assume a still more vertical orientation and the angle increases to 40° or more. The inclination is dependent upon the correlation between the size of the calvaria and the size of the face (cf. Fig. 168). The zygomatic arch which connects these two constituents of the skull takes a more vertical course the larger the face and the smaller the calvaria but a more horizontal one in case the proportions are reversed. I will return to this question later.

Schultz (1915) worked out a method for determining form and size of the squama of different races of modern mankind. He measured length and height of the squama taking its greatest longitudinal extension parallel to the Frankfort plane as length and the vertical between the vertex of the curved parietal margin and the auriculare as height. Schultz applied this method also to anthropoids, though their squama does not fit very well into such a scheme because of its rather different orientation and its triangular form (see above). In Table IX the length and height of the squama and the length-height indices of the *Sinanthropus* specimens are listed together with corresponding measurements and indices of modern man, the latter figures being taken from Schultz. The above figures prove that the *Sinanthropus* squama is much lower (average length-height index 49.7) than that of modern man (65.2); the length-height

Table IX

Length and Height (in mm.) and Length-Height Index of the Temporal Squama Using the Method by A. Schultz (1915) and His Figures for Modern Man

Specimen	Length	Height	Length-Height Index
Sinanthropus Skull III *r*	72.5	33	45.2
Sinanthropus Skull III *l*	74.0	33.5	45.5
Sinanthropus Skull V *l*	71.5	35.0	49.3
Sinanthropus Skull X *r*	70.5	39.0	55.3
Sinanthropus Skull XI *r*	63	29	46.0
Sinanthropus Skull XI *l*	62	35.5	57.3
Sinanthropus Skull XII *l*	74	36.5	49.3
Average of *Sinanthropus* male and female	69.6	34.5	49.7
Average of different races of modern mankind, male and female	64.4 (51–78)	42.0 (32–54)	65.2 (49.4–87.5)

index of the latter shows a minimum value of 49.4 only for certain races. When the length and height measurements of the *Sinanthropus* squama are given in a way more adapted to its triangular form, namely with the hypotenuse as basis and the distance from the sphenoid angle as height, the average index is higher (57.3) but still considerably below that of modern man. According to Schultz the index of the chimpanzee squama amounts to 25 and that of orangutang and gorilla to 43.0; these figures confirm the simian character of the *Sinanthropus* squama.

In the publication on the torus occipitalis (Weidenreich; 1940b) attention was already drawn to the particular development of the supramastoid crest which forms the boundary toward the mastoid portion. In accordance with the slanting position of the posterior portion of the squama (cf. Fig. 23 and the occipital views of Skulls XI—Fig. 64—and XII—Fig. 76) the crista supramastoidea bulges to such an extent as to represent the utmost lateral salience of the skull and thus resembles the conditions typical of anthropoids in which the prominence is still more accentuated as the nuchal crest extends forwards up to the ear-opening. In *Sinanthropus* there is no direct connection with the occipital torus, the crest terminating abruptly at the squamous suture and thereby marking the anterior border of the so-called incisura parietalis, an indentation between the parietal and mastoid margins of the temporal bone. This incisura (ip) is very distinct in all of the *Sinanthropus* specimens. Loth (1912) suggested that its formation is dependent upon the special development of the squama; the higher the squama, the more pronounced the notch should be. However, in Skull III (left side, Fig. 102) the indentation is very deep, despite the mastoid and squamous portions reaching up to about the same height.

As to the special relief of the external surface of the squama of modern man Schwalbe (1902, 1907) distinguished three eminences which he called protuberantiae gyri temporalis superiores, mediae and inferiores. He considers them to be correspondent to impressions made by gyri on the inner side of the squama. None of the *Sinanthropus* specimens shows any elevation which could really be interpreted as the reverse of such an internal relief. As I have already noted above, the bone is much too thick to permit those mutual relations. But linear crest-like elevations do occur in *Sinanthropus* as, for instance, in Skull V (Fig. 21), and more frequently patches of greater or smaller dimensions, rounded or polygonal in form; they are slightly deepened and demarcated from one another by low, smooth ridges. The same pattern is found in modern man also; here the patches indicate the insertion of small bundles of the

temporal muscle. In *Sinanthropus* the areas are merely deeper and run obliquely from above to below corresponding to the course of the muscle fibers. This conforms rather well to the interpretation that the pattern is less developed in the female *Sinanthropus* Skull XI than in the male Skulls III, X and XII.

Although the zygomatic process proper is missing in all of the specimens, it can be concluded from the appearance of what is preserved of its linkage with the squama that the distance of the zygomatic arch from the cranial wall, which spans the temporal fossa, was much greater than in modern man. The root proper of the process which establishes that connection shows a triangular shape with upper and basal surfaces. The latter carries the lateral portion of the so-called articular tubercle (see later), the former represents a broad groove widening anteriorly. Since the groove has not been given any special term, I propose to name it "sulcus processus zygomatici." The wider and shallower this sulcus is, the greater the distance of the arch from the cranial wall. In Skulls III and XI (right side in both cases) there is practically no indication of a groove but rather a wide, even upper surface, suggesting that the arch must have spanned the fossa temporalis to a considerable distance from the cranial wall as is true in anthropoids. The very strong structure of the crista supramastoidea which in *Sinanthropus* always appears as the continuous and salient posterior prolongation of the zygomatic root points to the same direction.

The lateral portion of the so-called articular tubercle which occupies the basal surface of the zygomatic process is missing in all of the *Sinanthropus* specimens but the medial portion located on the basal surface of the squama itself is more or less preserved in six cases. In his study of Skull III (Locus E) Davidson Black (1931) thoroughly describes the conditions of the tympanic region and the mandibular fossa but failed to mention those of the glenoidal area. But judging from the parasagittal craniograms with which he illustrates the description—Fig. 23 (Black)—and from the abbreviations he uses it is safe to deduce that Black failed to recognize any essential deviation from the conditions of modern man. Indeed, if one is contented by merely glancing at the region in question, the same conclusion will be reached; yet a more precise analysis, particularly if supported by a more abundant material, will reveal that some characteristic differences exist. First of all, there is no true "articular tubercle" in *Sinanthropus* if this term implies a transverse, cylindrical prominence as it occasionally occurs in modern man. In *Sinanthropus* Skull III (left side—Fig. 104,—the right being damaged within this region) the entire area before the mandibular pit, which embraces not only the squama but also the sphenoid portion medially adjacent thereto and extending forwards to the root of the pterygoid process, is not merely flat, so that it merits the term "planum" rather than "tuberculum," but even distinctly depressed at the very rim of the fossa. Unfortunately, it is impossible to ascertain how far forward the cartilaginous coating originally extended in Skull III because of the secondary attrition of the articular facet. However, in Skull XI (Fig. 110) in which the middle portion of both sides is preserved the facet extends no further forward than is true in modern man. In this case the facet is slightly elevated. A "planum" preglenoidale is also very distinct in Skull V (Fig. 26) while Skull II (Fig. 16) somewhat resembles Skull XI inasmuch as the facet, in spite of its trochlea character as a whole, is elevated. In all of the remaining specimens the area is either not preserved or damaged.

Regarding the mandibular fossa Davidson Black (1931) already called attention to the fact that it is "deeply excavated and essentially hominid in form." In some cases, particularly in Skull V (Fig. 26) the fossa is very short in sagittal direction but at the same time very deep.

The same conditions are found in Skull XI (left side, Fig. 110), a fact rather noteworthy on account of the first mentioned skull belonging to a male and the second to a female individual. It is difficult to express the dimensions and proportions of the fossa in figures, since there are no distinct and really comparable landmarks for its anterior and posterior boundaries; the former gradually continue into the preglenoid planum while the latter is quite generally formed by the crista petrosa of the tympanic plate. The medial and lateral landmarks are more easily distinguishable. The first is determined by the most prominent point of the entoglenoidal process formed in all cases of *Sinanthropus* by the squamous portion of the temporal bone; the latter is represented by the uttermost lateral extension of the fossa over the basal surface of the zygomatic process where it is distinctly indicated by a demarcation line. This lateral landmark has been preserved only in the right fossa of Skull III (Fig. 103) but can be approximately defined in most of the other cases. The depth can best be measured by connecting the anterior and posterior landmarks by a sagittal line and erecting a perpendicular to it within the deepest point of the fossa. The length, breadth and depth of the fossa, together with the indices (Table X) give a fair idea of the dimensions and proportions of the fossa, especially if compared with the corresponding figures of modern man and anthropoids.

In all of the *Sinanthropus* specimens the medial wall of the fossa consists exclusively of the squama itself which reaches down to the same level as the sphenoid, medially adjacent thereto,

TABLE X

Dimensions of the Mandibular Fossa in Prehominids, Modern Man and Anthropoids

Specimen	Length in mm.	Breadth in mm.	Depth in mm.	Breadth-Length Index	Depth-Length Index	Depth-Breadth Index
Sinanthropus:						
Skull III r ♂	18	25	11.5	72.0	63.8	46.0
Skull III l ♂	16	?	13.0?	—	81.3	—
Skull V l ♂	21	?	15.0	—	71.4	—
Skull XI l ♀	21	27?	15.0	77.7	71.4	55.5
Skull XII l ♂	18?	23?	15.0	78.3	83.2	65.2
Average	18.8	25.0	13.9	75.2	74.0	55.6
Pithecanthropus:						
Skull II ♀	28	23?	13	123	46.4	56.5
Skull IV ♂	28	28?	18	100	64.3	64.3
Modern man:						
European ♂	23.5	21.5	12.5	109.5	53.2	58.2
New Caledonian ♂	27.0	26.0	16.5	104.0	61.1	63.4
Amerindian ♀	23.0	26.0	16.0	88.4	69.5	61.5
Average............	24.5	24.5	15.0	100.0	59.6	60.5
Anthropoids:						
Gorilla ♂	27.0	46	10	58.7	37.1	22.1
Orang ♂	18	40	9	45.0	50.0	22.5
Chimpanzee ♂	25	29	7	86.3	27.9	24.1
Average............	23.3	38.3	8.7	60.7	37.4	22.7
Paranthropus robustus Broom	27	29	11.5	93.0	42.6	39.7

or, in other words, the entoglenoidal process is formed by the squama in its entire height. The foramen spinosum preserved in Skulls III (Figs. 103 and 104; fsp) and V is situated on a plane area very close to the sphenosquamous suture. These conditions are quite different from those of modern man (Fig. 121). In the latter the sphenoid very frequently develops a more or less pointed process—processus spinosus—which descends much further downward than the squama and so forms the lower portion of the medial wall of the fossa. The foramen spinosum is situated at the medial slope of the process (pfs). Not infrequently, however, apparently regardless of races, the squama alone forms the entoglenoidal process as is found in *Sinanthropus*.

There is a very strange feature obviously peculiar to *Sinanthropus* which occurs neither in man nor in anthropoids. The medial wall of the fossa is not concave conforming with the contour of the whole fossa but rather convex projecting toward the tympanic plate; for this reason the posterior medial part of the fossa appears as a narrow recess which looks like a cleft between squama and tympanic plate. The recess is well developed in Skulls III (left side), V and XI, while on the right side of Skulls III and XII convexity and recess are absent (cf. Figs. 24, rm; 103; 104 rm; 110 rm; 112). The special formation of the medial wall is apparently connected with the antero-posterior compression of the fossa and the degree of perpendicularity of the tympanic plate.

As follows from the foregoing description, the *Sinanthropus* mandibular joint is characterized by a deep and narrow fossa mandibularis with the articular tubercle missing or very flat. This merely refers, as explained above, to the medial portion of the so-called articular tubercle while laterally, within the region of the zygomatic process, a true tubercle exists. Lubosch (1906a) proved that there is a great variability in the development of the articular tubercle of man. It can be almost completely flat or rise to a considerable height as shown by Lubosch's Figure 6. That those differences do not depend upon accidental conditions of the dentition follows from Kieffer's (1908) observations, according to which 80 per cent of negroes with faultless dentition had a flat tuberculum while 65 per cent of Europeans (Alsatians) with equally faultless dentition had a high one. The drawings supplied by Lubosch reveal that the height or, more correctly, the development of the tubercle depends chiefly upon two factors, namely first on the form and size of the mandibular pit behind the tubercle and secondly on the special position of the basal surface of the sphenoid or the fossa infratemporalis in front of the tubercle. As may be seen from lateral views of the human skull, there is a great variability in the position of the sphenoid. In some cases the roof of the infratemporal fossa appears more or less horizontal when the Frankfort plane is taken as standard; in others the roof ascends steadily from the tubercle region forward to the orbital fissure. In the latter cases the tubercle seems to be more prominent since the angle between the preglenoidal planum and the anterior wall of the mandibular fossa appears as a more acute one. In other words, the tubercle is higher than in the first mentioned cases where the angle tends to be obtuse. On the other hand, the prominence of the tubercle will be more accentuated the narrower the mandibular fossa and the steeper its anterior wall. Diagrams given in Fig. 113 represent sections through the base of the temporal bone of prehominids, modern man and anthropoids from the sphenoid backward to the occiput; the sections are drawn through approximately the middle of the mandibular fossa somewhat obliquely from in front and medially to back and laterally, in order to include as much as possible of the planum preglenoidale.

The second factor responsible for the accentuation of the tubercle is the appearance of the fossa mandibularis. The wider and flatter the fossa, the less pronounced the tubercle (cf.

Fig. 113). The depth and the sagittal length of the fossa seems to depend chiefly upon the position of the tympanic plate. I shall return to this question later in describing the tympanic portion. Here it is sufficient to point out the principal difference of its position in anthropoids and man. As is evident from Figure 113, the tympanic plate is in an absolutely horizontal position behind the region of the fossa mandibularis in gorilla (H, and Fig. 123) and chimpanzee (K, and Fig. 122). The fossa is here merely represented by a narrow and flat transverse furrow the posterior wall of which is formed by the postglenoid process (pp). The process is strictly confined to the lateral moiety of the fossa; this is the reason why the process was not touched in the diagram of the gorilla (H), while it is fully indicated in that of the orang-utang (I) and approached in that of the chimpanzee (K, and Fig. 122). In typical cases of modern man (Fig. 121), however, the tympanic plate is placed almost vertically, forming so the posterior wall of the fossa while the postglenoidal process has been reduced to an unimportant elevation, if developed at all.

In comparing the conditions of the entire articular region of modern man with those of anthropoids the majority of authors concluded that the latter differ from man in not having an articular tubercle but instead a plane facet. As Figure 113 shows, however, the fundamental difference does not consist in the existence of the tubercle which in man also may be submitted to great variations in degree of development but rather in the formation of a mandibular fossa. In anthropoids this fossa is but faintly represented by a shallow and narrow depression (Fig. 113, H–K and Figs. 122 and 123) whereas in man (Fig. 113, D, E and Fig. 121) it is a deep and relatively wide cavity.

It is a well known fact that depth as well as shape of the fossa of modern man are subjected to great variations. Sullivan (1917) who studied these conditions in a series of Eskimo skulls found the fossa:

deep and short in 21 per cent
medium and short in 15 per cent
shallow and elongated in 31 per cent
flat and elongated in 33 per cent

Campbell (1925) reported that in skulls of Australian aborigines the depth varies from 1.5 to 8.0 mm. In *Sinanthropus* (Fig. 113, A–C) the narrowness and depth is still more pronounced than in the average modern man and, therefore, the divergence from the anthropoid type of the fossa is greater. The figures given in Table X, despite all their inexactness (see above), show that the depth-length index in anthropoids amounts only to 37.4 and that of modern man to 59.6 while it is 74.0 in *Sinanthropus*. The ratio between length and breadth indicating the narrowness of the fossa equals 100 in man but only 75.2 in *Sinanthropus* or, in other words, while in modern man length and breadth have the same ratio, the length is only three quarters of the breadth in *Sinanthropus*. *Pithecanthropus* (Fig. 113; f; G) is in this respect like the hominids; yet it is not without interest to note that even the male individual (G)—Skull IV—approaches recent man closer than *Sinanthropus* (depth-length index 64.3; breadth-length index: 100).

The fact that *Sinanthropus* is not intermediate between man and anthropoids as may have been expected but rather exaggerates, as it were, the human character supplies a valuable hint as to the causes which underlie the formation of the human fossa mandibularis. As already indicated above, the turning of the tympanic plate from horizontal orientation as in anthropoids (Fig. 113; H–K) into an almost vertical one as in man (E), already expressed in *Sinanthropus*

(A–C), is certainly one of the causes. This change in position is, of course, in itself only a consequence of the altered orientation of the occipital part of the cranium which in turn is due to the expansion of the brain. In proportion to the descending and forward moving of the occipital bone, as indicated in the alteration of the position of the occipital foramen (see later), the mastoid portion of the temporal bone including the tympanic plate moves downwards and forwards, the plate thus forming the posterior wall of the developing mandibular fossa. Although such conclusion seems to be cogent, the alteration of the position of the occiput alone cannot be made responsible for the formation of the fossa. For a fossa already existed in *Paranthropus robustus Broom* [1] (Fig. 113, L) in which the occiput descends, it is true, to a lower level than in gorilla (H) and orang-utang (I), but not so low as in chimpanzee (K) in which a true fossa is absent. The *Paranthropus* fossa is apparently deeper than in any other anthropoid as is evident from the depth-breadth index (Table X)—39.7 as against 22.7 in anthropoids and 55.6 in *Sinanthropus;*—thus, there is reason to believe that the anthropoids originally had a fossa.

Although the *Paranthropus* skull shows general anthropoid characteristics, its dentition differs and conforms to the hominid pattern. As in the latter case, the canines are small, neither does *Paranthropus* show prognathous upper and lower jaws as is true for anthropoids. These differences, on the one hand, and conformities, on the other, suggest a possible correlation between the formation of the fossa mandibularis and the size of the canines. But in attempting to comprehend the nature of such correlation, it is realized at once that depth or flatness of the fossa cannot involve the manner of masticating for the simple reason that even in modern man with his deep fossa the condyle of the mandible at no time rests on the floor of the fossa; even if the mouth is closed, it merely comes into contact with the posterior slope of the articular tubercle. The reason for such arrangement is, of course, the existence of the articular disc which tends to level the unevenness of the glenoidal surfaces caused by the incongruity of the two bony constituents of the joint. That such a tendency actually exists may be deduced from the variability of the thickness of the disc which surprisingly corresponds to the varying depth of the mandibular fossa. Lubosch (1906b) found that "the disc fails to conform to the height of the tubercle in such a way that a thin disc would correspond to a high tubercle but, quite on the contrary, the disc conforms first of all to the form of the mandibular fossa." Lubosch illustrates these conditions by sagittal sections through the joint with the disc in original position. The four most characteristic examples were taken from Lubosch and are given here in Fig. 114. The fossa portion of the disc is thicker the deeper the fossa (A and B); the portion inserted between the anterior part of the condyle and the posterior slope of the articular tubercle is the thinnest, while the portion corresponding to the anterior slope of the tubercle again is thicker. Unfortunately, as far as I know, no similar investigations of anthropoid mandibular joints are available in the literature, especially such dealing with the conditions of the disc. The only information on this subject is contained in Bluntschli's (1929) paper on the masticatory musculature of the orang-utang in which he also discusses the change of the joint during growth. Sagittal sections through the disc (Fig. 115, copied from Bluntschli's Figure 2) reveal that it is thinner than in man and there is no essential difference in thickness between its fossa portion proper and that facing the anterior area of the tubercular facet.

Lubosch's observations have been confirmed by Petrovits (1930). He found the size of the mandibular fossa of adult man in proportion to the size of the disc: "In cases of large and

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[1] I am indebted to Dr. R. Broom for his kind permission to make use of the cast for the diagrams.

thick discs the fossa was correspondingly large and deep while in cases of small and thin discs the fossa was shallower and flatter. On the other hand, no correlation has been found between the size of the condyle and that of the fossa."

All these facts indicate that the mechanism of the mandibular joint is the same in principle in man and anthropoids, regardless of how the bony constituents of the joint may be shaped in details. All anthropoids show absolutely free movements in this articulation; the jaw can be depressed or raised or may be carried forward or backward or from side to side. When such movements are hampered by the inter-locking of long upper and lower canines, the opening of the mouth slightly restores freedom and permits extensive grinding movements. There is a distinct tendency in anthropoids to execute these movements despite their impeded dentition. The high degree of attrition to which not only the canines but also the molars of older specimens are subjected give evidence to what extent grinding movements may overcome even a strongly obstructive dentition. In a rather interesting study Sicher (1931) showed that the dentition of *Colobidae*, particularly the development of long canines in both jaws, fails to harmonize with their phyllophagous habits to which the stomach has already become adapted. While the mandibular joint represents a flat articular facet and thus permits movements in all necessary directions, the canines must first be rounded off as demonstrated by the occurrence of fractured and split teeth, a condition which increases in intensity with advancing age.

I am, therefore, inclined to interpret the development of the fossa mandibularis in man, already established within the *Sinanthropus* stage of evolution, not so much an indication of small canines but rather the manifestation of the tendency to transform the base of the cranium in correlation with the expansion of the brain. In any case, the depth of the fossa is in no way connected with the diet. Folli (1899) claimed to have found that the human fossa is deeper in a frugivorous population than in a carnivorous one. Sullivan (1917) shares the opinion that the variations in the glenoid fossa are due to function, although he found great differences within the same population. Campbell (1925) is, with right, sceptical in this regard. According to him "no simple causal relation exists between occlusal attrition due to mastication and shallowness of the fossae, but undoubtedly other factors must be taken into consideration" and indicatively he adds: "one of which is probably the nature and thickness of the interarticular disc."

The topographic relation between mandibular joint and braincase is also influenced by the expansion of the brain. In modern man the lateral part of the middle cranial fossa lies entirely over the mandibular fossa so that even the lateral extremity of the latter remains within the sagittal plane of the cranial wall (Fig. 116). In gorilla, however, the greater part of the mandibular fossa is situated outside of this plane (Fig. 118). This change of the relative position apparently is the result of the lateral expansion of the human brain, as can be easily deduced from the differences in the distances of the cranial wall and the mandibular fossa from the midline of the skull. As the figures of Table XI show, in gorilla as well as in man, the center of the fossa mandibularis is placed 60 mm. lateral of the midline, but the interior surface of the cranial wall rises 10 mm. medial of this point in gorilla, but 10 mm. lateral of it in man. In other words, while the distance of the fossa center from the midline of the skull remained unaltered, the cranial wall of the human braincase has shifted laterally by 20 mm. as compared with gorilla, or by 35 per cent of the entire skull-breadth. In *Sinanthropus* (Fig. 117) the center of the mandibular fossa coincides with the internal surface of the wall itself, the latter thus occupying a position exactly between gorilla and man; the lateral expansion of the cranial wall amounting, therefore, here to only 18 per cent of the skull breadth. *Pithecanthropus* (Fig. 119) is like *Sinanthropus*

TABLE XI

Distance (in mm.) of the Mandibular Fossa and the Cranial Wall from the Mid-Line of the Skull

	Internal Surface of the Wall at the Porion Level	Lateral Extremity of the Fossa	Medial Extremity of the Fossa	Center of the Fossa
Gorilla ♂ (A.M.N.H., no. CA 1460)	50	79	41	60
Modern European ♂ (A.M.N.H., no. A 1435)	70	66	35	60
Sinanthropus Skull III	55	67	43	55
Pithecanthropus Skull II	56	60	38	49
Paranthropus robustus Broom	50 ?	69 ?	50 ?	60 ?

in this regard, while *Paranthropus* (Fig. 120) follows rather the line of gorilla. The special location of the mandibular fossa, however, has no bearing upon its development, for its position lateral from the cranial wall as displayed by gorilla is a secondary character. In prosimians and platyrrhines the fossa has the same orientation as in prehominids and is distinctly more developed than in anthropoids though flatter in the prosimians than in the platyrrhines; yet there is no essential difference in the relative canine size between platyrrhines and great apes.

Regarding the development of the processus postglenoidalis, Black's statement (1931) of the non-existence of a true process in *Sinanthropus* is correct with some reservation. As has already been mentioned, there is indeed no large, far projecting process as it is characteristic of gorilla and orang-utang, but a low, broad-based transverse ridge marks the boundary between the lateral moiety of the mandibular fossa and the tegmen pori acustici behind it. This ridge—crista postglenoidalis—is found in all of the *Sinanthropus* specimens; it is best preserved in Skull III (Figs. 103 and 104, cpg) whereas it is broken off, together with the zygomatic process, in the remaining specimens. The ridge apparently represents all that is left of the strong barrier which in lower primates hinders the eventual posterior movement of the mandibular condyle. With the downward shifting of the occiput the mastoid portion and the tympanic plate function more and more as a back-wall of the mandibular joint, the postglenoidal process becoming thereby superfluous and reduced. In the two *Pithecanthropus* skulls (Skulls II and IV) in which the auditory region is preserved the postglenoid process is of exactly the same appearance as that of *Sinanthropus* and, according to Broom's description and illustration (1939a), the same is true of *Paranthropus*.

The postglenoid process of modern man presents a rather interesting problem. It is a well known fact that it varies considerably in degree of development regardless of races. European skulls may be found in which the process reaches size and degree of independence which almost equals the conditions in chimpanzee while it may appear as a negligible tubercle in Australian aborigines. Cabibbe (1902) was first to direct attention to still other cases. The process, particularly if of medium size, occasionally shows at its free end a fine transverse groove which devides the entire length into an anterior and posterior section. The former has the aspect as if it were shaped by strong pressure from in front and pressed backwards and downwards toward its posterior section and the tympanic plate. One thus arrives at the conception that the condyle may play an active rôle in modelling the back-wall of the joint, an idea further corroborated by the particular form of the tympanic plate to which I shall refer later. The reason why the postglenoid process appears to be larger in some cases of modern man than in all of the known types of prehominids is difficult to explain on the sole basis of the fossil material

now available. However, the same degree of variability as found in modern man seems to have existed already among the skulls of the Neanderthal group. According to Klaatsch (1902) the process is missing in both Spy skulls while it is well developed at least in one of the Krapina fragments (cf. Gorjanovič-Kramberger, 1906); the latter is also true of the Rhodesian skull the postglenoidal process of which was described by Pycraft (1928) as "conspicuously large, and swollen." The only conclusion to be drawn from these facts is the assumption that there were at least two different strains in the ancestry of man, one in which the postglenoidal process was lost very early and a second one in which it persisted much longer. How and to what degree these strains were intermingled remains a pure guess as long as we do not know more about the forerunners of the prehominids and the different lines which compose the Neanderthal group.

The interior surface of the *Sinanthropus* squama differs in two essential features from that of modern man. According to the restricted height and the greater length of the entire squama, as described above, the lateral wall of the middle cerebral fossa, as far as it is formed by the squama, is lower and relatively longer than in man. On the other hand, there is a further reduction of this wall since the space occupied by the squamous suture is much broader in *Sinanthropus*. In the two cases where direct measurements are available, as in the right and left temporal bone of Skull III, the suture section is 22 mm. broad at the widest, and 14 mm. at the narrowest whereas in modern man these measures are 15 mm. and 6 mm., respectively. In *Sinanthropus* as well as in modern man the broadest part of the squamous suture is found toward its anterior extremity and the narrowest near to its posterior part. The greater breadth of the *Sinanthropus* suture is, of course, only a consequence of the difference in the thickness of the bone.

The wall of the cerebral fossa in *Sinanthropus* diverges from that of man by being more concave, aside from the fact that it is lower; in other words, the wall of the squama does not meet the superior surface of the pyramid at a right angle but comes down in a wide curve. The juga and impressions are much more effaced than in modern man; this is particularly true for the impression which corresponds to the inferior temporal convolution, it usually is rather well marked in man but indistinguishable in all of the *Sinanthropus* specimens.

Schwalbe (1902, 1907) and Wallisch (1913) stress the occasional occurrence of a distinct jugum corresponding to the summit of the mandibular fossa. Count Spee (1896) considers the presence of such a jugum apparently as a very common occurrence; for he gives the following description of the floor of the cerebral fossa: "Immediately in front of the tegmen tympani there always is a thin area, often projecting toward the cranial cavity beneath which the mandibular fossa is situated." As mentioned by Black (1931), in *Sinanthropus* Skull III (right side) there is an artificial penetration at this very place. Although, in addition to this, the floor of the cerebral fossa is slightly elevated around the hole, I doubt whether there really is any correlation between the mandibular cavity and the juga of the cerebral fossa, for even at the perforation the thickness of the bone measures 2.5 mm. while in the other specimens the thickness within this region is even greater, varying between 3 mm. to 4.5 mm. This infers that even there where the floor of the cerebral fossa is thinnest it nevertheless equals the average thickness of the cranial wall of modern man.

Tympanic plate

The tympanic plate of *Sinanthropus* differs from that of recent man in position, form and thickness in a rather characteristic way. The differences concerning the position involve its situation and orientation, first in regard to the auriculare or the base of the zygoma, second in

regard to the horizontal plane of the skull base and third in regard to the angle which the transverse axis of the plate forms with the axis of the pyramid. With reference to the first point, Davidson Black (1931) already pointed out the fact that in *Sinanthropus* Skull III the zygomatic crest forms a widely overhanging roof above the porus acusticus externus. In other words, the porus lies medially far from a sagittal plane, laid through the auriculare. The same peculiarity is found in all of the *Sinanthropus* specimens. The distance between the auriculare-plane and the most lateral point of the porus edge amounts to 10–15 mm. In modern man the distance varies but hardly ever exceeds the lowest mark of this scale. Among the anthropoids only orang-utang shows conditions similar to *Sinanthropus* while chimpanzee approaches modern man, and in gorilla the porus at times projects even more laterally than the zygomatic crest itself. The second difference in the position of the *Sinanthropus* tympanic plate concerns the manner in which it overlies the petrous portion. In modern man (Fig. 121) the plate (ty) is orientated almost vertically; that is, it has an upper and a lower margin. The former joins the squamous portion along the Glaserian fissure, the latter is free and represents the crista petrosa or, in other words, it covers the frontal side of the petrous portion deviating only slightly from vertical orientation by a backward inclination. In any case, the plate appears as the posterior wall of the mandibular pit (fm). In anthropoids, as already noted above, the conditions are different; in chimpanzee (Fig. 122) the tympanic plate is horizontally orientated covering the entire base of the petrous portion; there is, therefore, no upper and lower margin but instead an anterior and posterior one, the former joining the squama in the Glaserian fissure as in man while the latter comes in direct contact with the mastoid portion. Orang-utang and gorilla (Fig. 123) are closer to man in this respect but the tympanic plate is much narrower than in man and inclines more backward; I shall return to these differences later when discussing the form of the bone. In *Sinanthropus* the orientation of the tympanic plate is intermediate between that of modern man and chimpanzee, thus rather resembling that of gorilla and orang-utang; in other words, it is less vertically orientated than in modern man but not as prone as in chimpanzee. The third difference in the position of the tympanic plate concerns the direction of its transverse axis. Klaatsch (1902) recorded for the two Spy skulls that the Glaserian fissure runs at right angles to the mid-sagittal line of the skull whereas in modern man it forms an acute angle, a statement veryfied by Loritz (1916) on 100 Bavarian skulls. An acute angle varying from 56° to 80° was found by this author in 82.5 per cent, and an angle from 80° to 92° in 17 per cent. It follows from this investigation that a transverse course of the Glaserian fissure occurs also in modern man, though the acute angle predominates. In the four *Sinanthropus* cases in which this angle can be measured it varies between 87° and 90°, the average being 88°. Since the angle, however, is about the same in anthropoids, the direction of the Glaserian fissure fails to furnish a reliable criterion for the actually existing differences in the orientation of the tympanic plate. I shall revert to this question later.

The general form of the tympanic plate shows a great variability in modern man. There are such which are rather short in transverse direction but relatively long vertically. In *Sinanthropus* the number of completely preserved bones is too small to ascertain the average conditions but, at any rate, the bone is much shorter than in anthropoids where it reaches an extraordinary extent in transverse direction (Figs. 122 and 123). The *Sinanthropus* plate, however, differs strikingly from the tympanic plate of modern man in regard to the formation of its surface. In man the surface is more or less concave and concordant with the curvature of the mandibular fossa which it joins. In *Sinanthropus* the surface is plain or even convex projecting

toward the fossa and resembles thereby somewhat the conditions which prevail in anthropoids. This difference seems partly due to the thickness of the *Sinanthropus* plate which even within its central part, where it is thinnest, exceeds that of modern man two or three times. The great thickness of the *Sinanthropus* plate which involves all its parts is also responsible for the greater smoothness of the surface compared with that of modern man and especially for the bluntness of all the edges and points of the bone. The thickness is particularly true for the free annular border that encircles the porus acusticus. The border tapers toward the anterior and posterior ends of the ring where they apply closely to the squamous and mastoid portions, respectively, but elsewhere and in particular at the floor of the porus the bone is very thick and the border itself more or less rounded. Only on the left side of Skull V (Fig. 24) does the floor taper toward the rim and exhibit a slight but distinct striation. In modern man the whole free border and especially the floor of the porus is always thicker than the remaining parts of the tympanic plate. This thickness can reach extraordinary dimensions as is the case in Eskimos (Oetteking, 1930; Stewart, 1933) and certain groups of Amerindians (Stewart, 1933; Möller-Holst, 1933). The fact that it is a common occurrence in Neanderthal man has been stressed by Klaatsch (1902) and Boule (1911). The conditions of the tympanic plate of *Sinanthropus* contribute toward our understanding of the discussed feature in Neanderthal and modern man. In the prehominid stage the entire plate is thick, much thicker than in later evolutionary stages. The general thickness gradually becomes lost, except for the border that encircles the porus; this ring as a rule also participates in the decrease but not to such an extent as the other parts of the plate. In certain races of modern mankind (Eskimo and Amerindians) the original thickness of the border may even persist and thus appear under the form of a localized hyperostosis of the bone.

The tympanic plate of Skull III shows on both sides a very conspicuous peculiarity, as thoroughly described by Davidson Black (1931): the free border and the lateral portion of the floor of the meatus is divided by a slit into an anterior and posterior lip (Figs. 103 and 104). On the right side (Fig. 103) the slit retains its narrowness up to the end, while on the left (Fig. 104) it widens to a spherical foramen. The two lips and the margins which bound the slit are very thick and like all the other parts of the plate rounded off. In none of the five other temporal bones of *Sinanthropus* do similar conditions exist, but in all these cases the floor of the meatus is closed and the free border unindented. Only in Skull XI (Fig. 110) is there a deep cut on the lateral extremity of the basal surface of the plate which extends to the free border indenting it, too, but fails to penetrate the floor. In my first publication on *Sinanthropus* (1932) in which I discussed on the basis of casts some of the features described by Black I doubted the constancy of the slit and whether it was specific of *Sinanthropus;* I rather considered it one of those abnormalities not infrequently found in modern man, in particular within certain races, where the hiatus between the annular and the basal portion of the tympanic plate, which persists for a relatively long period during normal ontogenetic development, failed to close. The foramen known as "Huschke's foramen" may persist even in adult individuals; Oetteking (1930) found it in up to 33.3 per cent among certain tribes of Amerindians, Akabori (1933) in 32 per cent of prehistoric inhabitants of Guam and in 12 per cent of recent North Chinese. In almost all of these cases there is only a smaller or larger gap in the floor of the meatus. But there also occur such in which the free border is indented and the fissure terminates with a spherical hole; such a case is depicted by Bürkner (1878) and reproduced here in Figure 124. The fissure of the left tympanic plate of Skull III (Fig. 104) corresponds entirely to that described by Bürkner

with the exception that the bone is by far thicker in *Sinanthropus* and lacks the second and third central perforation recorded by Bürkner.

In view of these facts, no other conclusion can be drawn but that the indentation of the tympanic plate in Skull III is an individual malformation caused by a retardation of the normal closure of the infantile gap. In modern man this closure takes place at the age of four or five years. The age of *Sinanthropus* Skull III is debated. Davidson Black (1931) regarded it as that of an adolescent while I arrived at the conclusion (1935) that the individual was younger, not older than eight or nine years of age (see later). In any case, provided the conditions of closure were the same in *Sinanthropus* and modern man, the persistence of the fissure is an abnormality and cannot be considered a specific feature of *Sinanthropus*. Another possibility, however, remains, namely that there is a delayed closure of the infantile tympanic gap in *Sinanthropus*. Skull III is so far the only juvenile specimen in our cranial collection, but it must be borne in mind that the age of five years considered to be the time limit for closure in modern man may only apply to European races and not to others, particularly not to Mongolians among whom perforations may remain persistent up to 40 per cent in adults (see above).

The form of the aperture of the meatus is of certain interest in view of the widely divergent opinions as to its shape in primitive hominid types. Table XII gives length and height of the apertures of all the *Sinanthropus* specimens and the character of their special form. Length means the antero-posterior diameter, height the vertical diameter. It follows from the figures

TABLE XII

Diameters of the Aperture of the Meatus Acusticus Externus (in mm.) and the Character of Its Form

Specimen	Length	Height	Form Character
Sinanthropus Skull III: right	10.5	8.0	horizontally elliptic
left	11.5	8.0	
Sinanthropus Skull V: right	9.5	12.0	vertically elliptic
left	9.0	14.0	
Sinanthropus Skull XI: left	10.0	10.0	round
Sinanthropus Skull XII	11.0	9.0	horizontally elliptic

that the form of the aperture varies considerably even in the four *Sinanthropus* skulls available for such criterion, although the horizontal orientation prevails. In Skull X the aperture is narrowed in the middle of its height by an exostosis (see later), causing a dumb-bell-like form of the aperture. But in its general character also this aperture is horizontally elliptic. In the vertically elliptic form the greater diameter does not take a completely perpendicular direction but rather courses more obliquely from behind below to in front above. In regard to modern man the majority of authors agree that among the various groups of Amerindians the vertically elliptic form prevails; Oetteking (1930) found it in up to 77 per cent. The same is true of the Australian aborigines who, according to Fenner (1939), show an ellipse in up to 81 per cent with an upward direction of the greater diameter. That in European skulls the horizontally elliptic form is the most common, as claimed by Le Double (1903), sounds incredible in view of the obvious fact that every textbook I was able to consult gives only the picture of a vertically elliptic aperture.

It is interesting to note that in anthropoids the same form differences exist as in the hominids. There are chimpanzee skulls with round, horizontally or vertically elliptic apertures.

The same variation is found in *Pithecanthropus*. In Skull II (Fig. 259 B) the apertures on both sides are round or slightly horizontally elliptic while in Skull IV (Fig. 230) they are apparently vertically elliptic even if we make due allowance for the heavy antero-posterior compression this skull underwent before fossilization (cf. Weidenreich, 1940a). It is of great interest that Broom's *Paranthropus robustus* plainly deviates from the anthropoids and approaches the hominids in this regard. The aperture is round with a diameter of 11 mm. in each direction.

But another difference becomes evident when comparing the aperture of *Sinanthropus* and modern man with that of anthropoids. In the latter the aperture is strikingly small regardless of the size of the skull, its diameter hardly ever exceeding 10 or 6 mm. in one or the other direction. In *Sinanthropus* the average amounts to 11.5 mm. for the greater diameter and 8.9 mm. for the lesser one. In modern man measurements have been made available by Möller-Holst (1933), who compared the size of the aperture of South American Indians with those of Europeans (skulls from Sleswick-Holstein), and Stewart (1933). According to the first author the aperture of the latter is considerably larger than that of the former. The average of the greater diameter of the South Americans (normal skulls) totals 8.9 mm. and that of the European 11.2 mm. while the respective figures for the lesser diameter are 5.9 and 8.1 mm. After Stewart (1933) the average of the greater diameter of males and females of Eskimos and certain groups of North American Indians amounts to 10.7 mm. and that of the lesser diameter to 7.6 mm. The porus of the European skull, therefore, is larger than that of Eskimos and Amerindians. In any case, the aperture of the *Sinanthropus* meatus is wider in either dimension than the average of those of Europeans and Mongolians, at least as far as measurements are available.

The anterior wall of the auditory canal of *Sinanthropus* Skull X (Figs. 106 and 107) shows a very remarkable peculiarity; a typical exostosis arises and the border looks as if it were rolled up. The growth extends medianwards along the entire length of the wall which is broken off at a distance of about 15 mm. from the entrance. The exostosis is 14.5 mm. long and has the appearance of a rounded, narrow spindle flattened at its lateral end from front to back and at its medial end from above to below. The greatest diameter of the lateral extremity is about 3 mm. and that of the medial one about 4 mm. The posterior wall and the free border of the porus show no other exostoses but the entire posterior wall is rather thick measuring circa 6 mm. Such "ear exostoses" are not infrequent in modern man. For detailed information the reader is referred to Hrdlička (1935) who dealt with these peculiarities in a very exhaustive publication. Although Hrdlička stressed the fact that ear exostoses occur in almost all races of modern mankind, it is noteworthy that their occurrence is much more frequent in certain races and racial groups than in others. While found, for instance, in some Amerindian tribes in 12–30 per cent and in Polynesian up to 18 and 20 per cent, it has never been observed in Negros and Melanesians. Exostoses are apparently also very rare in whites; Hrdlička noted their occurrence in old Egyptians to be only 1.3 per cent; but no statistical investigations are available on this subject concerning the white race in general. The only fact we know (cf. Hrdlička, 1935) is that clinical cases of ear exostoses described by European and American authors in various publications from 1809, when first observed, until 1930 total only 214 cases all together, cases of stenosis and atresia of the meatus acusticus, though of different nature, being included. Therefore, the conclusion is justified that the occurrence of typical circumscribed exostoses like those found in *Sinanthropus* or Amerindians are extremely rare among the white race. Thus far, they have been unknown to occur in fossil man. If it is permissable to speak of percentages in an instance where the exostosis is found in one out of only seven cases,

we may say that in *Sinanthropus* it exists in 14 per cent. Hrdlička (1935) scrutinizing all the possibilities of the causes which may produce ear exostoses arrives at the conclusion that they "constitute a special complex or entity belonging not in the field of diseases but in that of abnormalities, and that they must be directly connected with neuro-vascular derangements which may be excited locally by different agencies, but which have their seat in the trophic nervous centers that control the bony structures of the external auditory canal." In other words, the exostoses certainly are not of pathological nature but we do not know why they are formed and why they have such a characteristic seat. That their predisposition is not restricted to recent and present man, as claimed by Hrdlička, is proven by their occurrence in *Sinanthropus*.

Petrous portion

As in modern man the lateral part of the inferior surface of the petrous portion of *Sinanthropus* is covered by the tympanic plate. But since this plate, as was described above, rests almost horizontally on the pyramid and fails to assume an almost vertical position a greater part of the pyramid is exposed in the former. This is especially true of the pyramid portion between the crista petrosa and the mastoid (cf. Figs. 103, 104, 108, 112 and 121). A second difference strikes the eye immediately. In modern man the exposed parts of the pyramid, including the entire apical region, appears as if the bone were eroded; in other words, the surface even where it is not pitted by canals or foramina is rather uneven, covered with small holes which alternate with tiny edges and points. In *Sinanthropus* this surface is smoother and much less perforated. Unfortunately, the parts adjacent to the apex of the pyramid are not preserved in any of the *Sinanthropus* specimens; it is, therefore, impossible to ascertain whether or not a foramen lacerum had developed to the same degree as in man. There is, however, reason to believe that it was not the case; for the apex, almost completely preserved on the right side of Skull III, is much fuller and more compact than in modern man. Anthropoids show similar conditions (Figs. 122, 123): the basal surface of the pyramid is smooth, the entire bone more massive and instead of yielding space to a foramen lacerum the apex leans rather tightly against the sphenoid and occipital bone. These differences in the appearance of the basal surface of the pyramid between *Sinanthropus* and modern man apparently are due to the same cause as those of the tympanic plate: the entire bone is much thicker, fuller and more solid in *Sinanthropus* than in man.

A second divergence in the general appearance of the basal surface of the pyramid concerns the orientation of the axis. In my very first publication on *Sinanthropus* (1932) I had already called attention to the fact that axes drawn in transverse direction through the tympanic plate and the pyramid fail to form a more or less straight line as in man (Fig. 125) but instead form an angle the vertex of which coincides with the carotid foramen (Fig. 126). In anthropoids (Figs. 127 and 128) the bend of the line is still more pronounced than in *Sinanthropus*. The reason for this difference is not an alteration in the direction of the axis of the tympanic plate but obviously that of the pyramid, which turns from a more antero-posterior direction in anthropoids to a more transverse one in modern man. *Sinanthropus* takes the middle line in this respect. Figure 129 shows the degree of the deviation of the pyramid axis from the mid-sagittal plane: in gorilla the angle of deviation is 15°, in the European (depicted in this Figure) 63°, and in *Sinanthropus* Skull III 40°. In the orang-utang given in Figure 128 the angle amounts to 30°. There also is a slight alteration in the direction of the axis of the tympanic plate with reference to the mid-sagittal plane, but the change hereof is insignificant when com-

TABLE XIII

Angles the Pyramid and Tympanic Axes Form with the Mid-Sagittal Plane, Given as Examples in Figures 125–129

Specimen	Deviation Angle of the Pyramid Axis	Deviation Angle of the Tympanic Axis
European ♂ (A.M.N.H. no. 1435A)	63°	78°
Sinanthropus Skull III	40°	94°
Gorilla ♂ (A.M.N.H. no. CA 1460)	15°	88°
Orang ♂ (A.M.N.H. no. CA 2511)	30°	82°

pared with that of the pyramid axis, as evident from Table XIII, and varies considerably according to the figures given above for the direction of the Glaserian fissure.

Figure 129 at the same time demonstrates that the alteration in direction of the pyramid is accompanied by a shortening of the length which may partly be responsible for it. As the erosion-like aspect of the entire basal surface of the human pyramid and particularly the diminution of its apical region proves, it was the seat of a reducing process that apparently is in connection with the shortening of the spheno-occipital portion of the cranial base. That such shortening actually takes place in the course of evolution can be proved by contrasting the basion-hormion length (hormion is the median point of the vomero-sphenoid suture) with the glabello-opisthcranion length of the skull. Table XIV shows their average and minimum-maximum values, as far as they could be determined on material at hand. It may be that an investigation

TABLE XIV

Greatest Length of the Calvqria (Glabella-Opisthocranion) in Proportion to the Spheno-Occipital Basal Length, in Man and Anthropoids

Specimen	Cranial Minimum-Maximum Length	Basal Minimum-Maximum Length	Index Minimum-Maximum	Index Average
Recent Man (regardless of races and cranial form)	166–199	22–31	11.8–18.5	15.0
Gorilla, adult	162–175	39–50	23.9–29.0	26.3
Orang, adult	112–143	37–48	30.8–39.9	35.2
Chimpanzee, adult	125–144	30–41	22.5–32.0	26.0

on a much larger scale will yield somewhat different minimum-maximum values but the average will remain unchanged. In any case, it follows from the figures in Table XIV that the spheno-occipital portion of the base is in modern man nearly half as long as that of gorilla and chimpanzee in proportion to the length of the braincase, and more than half as that of orang-utang: in modern man the index oscillates between 10 and 20, in gorilla and chimpanzee between 20 and 30 and in orang-utang between 30 and 40. That the shortening of the base is not a relative condition caused by the enlargement of the braincase but rather an absolute one follows directly from the figures of the basal length (cf. Table XIV). It is, of course, only the result of the transformation of the cranium which, as will be discussed subsequently, consists in principle of rolling up the braincase about a transverse axis which runs approximately from one porion to the other. The shortened pyramid turns in a more transverse direction. In none of the *Sinanthropus* specimens is the spheno-occipital portion preserved but there are distinct indications that the rolling-up of the cranium had as yet not reached the degree attained in man. The apical region

of the pyramid is much less reduced and the axis has not yet swung completely into the new direction.

As to the structural details of the *Sinanthropus* pyramid and tympanic plate connected therewith, one of the most striking features is the thickness of the crista petrosa and the development of a heavy, far projecting spine thereon which in some cases (Skull X, XI) assumes the form of a pyramid (Figs. 25, 26, 101–104, 107–112; scp). I called (1932) the spine "spina cristae petrosae" although it is not absolutely identical with the pointed elevation of the human crista petrosa which G. Schwalbe (1914) determined by this term. The human crista petrosa (Fig. 121) is represented by a thin blade-like edge which begins near the porus and ends near the anterior margin of the carotic canal retaining the same thickness in its entire length. In *Sinanthropus*, however, the crista rises immediately medialward from the porus to a huge spine and forms beyond it a ledge-like margin toward the jugular incisure and the carotid canal. The spine occupies about the same space as the styloid process; but as already stressed by Davidson Black (1931), a styloid process does not exist in *Sinanthropus*. Although the medial part of the pryamid is broken off or badly damaged in all of the specimens (Skulls V, X, XI, XII), with the exception of Black's Skull III, the spine and its median and posterior slopes are preserved in all of them and thus provide a criterion as to whether or not a styloid process existed.

In modern man the process rises behind the free border of the tympanic plate and presses it forward (Fig. 121, pst). In numerous cases the plate itself grows thicker where the process leans against it, and produces irregular projections which more or less surround the process, particularly on its medial side. This transformation of the tympanic plate has been termed "vagina processus styloidei." The processus styloideus has its root within the petrous portion just before the stylomastoid foramen; even if the process should be broken off at its very base, it remains recognizable in the majority of cases by a fine cleft that separates it from the surrounding bone.

No styloid process exists in *Sinanthropus*. The place immediately medial and anterior to the stylomastoid foramen where we should expect to find the process is characterized by the spina cristae petrosae (cf. Figs. 24–26, 106–110; scp) which is quite different from that of modern man because it consists of only a pyramid-like elevation of the tympanic plate. To be exact, the spine does not occupy precisely the same place as the vagina processus styloidei in modern man but rises a good deal more medially. Nevertheless, there is some indication that the spine and the formation that leads to the development of the styloid process are related to one another. In certain of the *Sinanthropus* specimens—Skull V (Fig. 26), Skull XI (Fig. 110), Skull XII (Fig. 112)—a narrow groove runs vertically along the posterior slope of the spine from the top to the base where it ends with a small foramen medial to the stylomastoid foramen (fps). In the juvenile Skull III (Figs. 103, 104) the spine is much less pronounced; in addition, there is no groove and no foramen medial to the stylomastoid foramen. Instead, the slope of the spine of the right side (Fig. 103) shows a transverse curved depression to which there is no analogous formation in any of the other specimens.

In a previous publication (1932) I already recorded the fact that none of the skulls of the Neanderthal group shows conditions similar to such in *Sinanthropus*. In all of them, the basal surface of the petrous portion and the tympanic plate are like those of modern man. The skull of La Chapelle-aux-Saints has a well developed styloid process and a distinct vagina as proven by Boule's figures and descriptions. The same is true of the two Spy skulls, according to Klaatsch (1902), and the Krapina temporal bones, according to Gorjanović-Kramberger (1906).

As to the Rhodesian skull Pycraft's description (1928) is not very definite in this regard; Pycraft stresses the fact that "the vaginal process which covers the base of the processus styloideus is unusually far from both the rim of the meatus acusticus and the mastoid" and in another connection the author speaks of the great distance between the vaginal process and "the styloid process immediately behind it." But he continues: "The vaginal process itself is wanting and was evidently but feebly developed: its position is shown by a deep groove." All of this phrasing indicates that no styloid process exists but it is not clear whether it was accidentally broken off or whether it was absent originally. As far as can be judged from the figures and cast, the first alternative is correct. That the tympanic plate and pyramid of the Rhodesian skull show the characteristics of modern man is proven by the orientation of their axes: it fails to differ from the conditions of modern man. Of special interest are the Ngandong skulls. The styloid process is wanting but there is a distinct vagina. Whether the process was missing originally or accidentally is difficult to tell; in any case, the orientation of the axis is similar to that of *Sinanthropus*. In the two *Pithecanthropus* Skulls II and IV in which the temporal bones are preserved the styloid area is damaged.

The only author who noted the variation of the styloid process and its vagina in modern man is F. Wood Jones (1931). He states that the fusion of the process to the skull by its envelopment in the vagina is a human characteristic. This fusion process may have failed when the styloids are reported as absent; when present, they may be well developed or represented by the merest rudiments. Wood Jones (1931/34) found the styloid process absent in 13 per cent of Hawaiian skulls, in 20 per cent of Guam skulls and in 18 per cent of North Chinese skulls; it was rudimentary in 15, 8 and 19 per cent, respectively. Fenner (1939) reported that the vagina processus styloidei is very variable in Australian aborigines but he records its presence in 100 per cent, while he found the styloid process only in 77 per cent of male and 66 per cent of female skulls. His additional remark: "When present the process was often quite small, and the large long styloid processes characteristic of European skulls were rarely seen," indicates that the author considers the absence of the process as an original and not accidental occurrence. From Fenner's statement it may be deduced that there seems to be a decisive difference between *Sinanthropus* and modern man, even in those cases in which the styloid failed to develop: a vagina is always present in modern man while in *Sinanthropus* its place is occupied by a specifically formed spine.

The clue for the differences within the area of the styloid process in *Sinanthropus* and modern man and its variability is furnished by the conditions in anthropoids. As I have already shown in 1932, there is a spine-like elevation of the crista petrosa in all three anthropoids, but even in the male gorilla (Fig. 123) it scarcely ever attains the bulkiness and distinctness true for the adult *Sinanthropus* skulls. In any case, this spine appears completely independent of the styloid process behind it. In gorilla the process itself is usually completely wanting (Fig. 123), its place being occupied by a furrow which courses along the latero-posterior slope of the spine and continues into a foramen of about the same size as the stylomastoid foramen. This foramen is situated directly lateral to the spine at a distance of circa 6 mm. In chimpanzee (Fig. 122) the conditions are similar, with the only difference that from the foramen a fine and short piece of bone protrudes which obviously corresponds to the styloid process of man. The foramen stylomastoideum is not directly lateral to this as in gorilla but behind and lateral. Orang-utang resembles chimpanzee in this respect but the styloid process is usually much thicker than in the latter case although there is no difference in length. Therefore, even if a styloid

process is developed in anthropoids, in no instance does it come into close connection with the crista petrosa nor is the latter transformed into a vagina as is true in man.

It follows from this comparative review that *Sinanthropus* represents indeed in the feature in question a primitive stage very close to that of gorilla. According to Flower (1870) the styloid process of man consists of two portions: the tympanohyal which forms the basal portion and lies enclosed in the pyramid within a canal between the tympanic and periotic bones, and the stylohyal which forms the distal portion and is attached to the former by a ligament or more usually anchylosed with it. "The *Simiina* are remarkable," says Flower (1885), "in never, or very rarely, having an ossified stylohyal; but on looking closely at the base of the periotic, immediately to the anterior and inner side of the stylomastoid foramen, a very small depression in which there is sometimes a minute ossified tympanohyal can generally be seen. To this the ligament representing the stylohyal is attached." The ossification of the stylohyal and its anchylosis with the tympanohyal in *Catarrhinae* occurs quite independently of family or genus. In the baboon, for instance, there is a short but very strong styloid process similar to that found in orang-utang. The styloid process of modern man apparently is again a new acquisition while in *Sinanthropus* the stylohyal was probably not ossified or, if so, not anchylosed with the tympanohyal.

Still another feature remains to be noted concerning the styloid process. Boule (1911) and later H. Martin (1923) found the styloid process of the La Chapelle-aux-Saints and La Quina skulls, respectively, much further removed from the porus meatus acustici than in modern man. Martin states that this distance measures 20 mm. in the La Quina skull while only 15 mm. or less in modern man. I already pointed out that the tympanic plate of the anthropoids is much longer in transverse direction than that of man (cf. Figs. 121–123; 129) while *Sinanthropus* takes an intermediate position in this regard. It, therefore, appears plausible that the distance of the styloid process from the free lateral border of the plate is greater in *Sinanthropus* than in man. Since, however, a styloid process did not develop in this hominid the distance between the spina or, more correctly, the pit behind it and the border of the posterior wall of the porus must be taken as an equivalent. In the seven cases of *Sinanthropus* in which this distance can be measured with some reliability it is 18–22 mm. This is more than in modern man and about the same as in the La Quina skull.

Another interesting feature of the *Sinanthropus* tympanic-pyramid region is the existence of a small, round, tuber-like elevation which marks the medial anterior end of the tympanic plate and bounds from above the entrance into the canalis musculotubarius. I called (1932) this tuber "processus supratubalis" (cf. Figs. 103 and 104; ptu); it is only preserved in Skull III, but broken off in all of the other specimens. In modern man (Fig. 121) the process is not developed at the entrance to the canal, due to the reduction of the tympanic plate in size and thickness. But it is a characteristic formation in anthropoids (Figs. 122 and 123; ptu) where it attains considerable dimensions.

The carotid foramen does not differ from that of modern man regarding its general position. But I have the impression that it is slightly smaller than in modern man though its difficult to verify it by measurements. There is a real difference, however, in the size of the jugular fossa. Regardless whether it concerns the right or left side, the concavity near the posterior margin of the pyramid that represents the fossa is much flatter, narrower and shorter than is the rule in modern man (Figs. 26, 110, 112, 103, 104; fj); only in the juvenile Skull III is the concavity large and more pronounced and approaches thereby the human type.

The internal surface of the pryamid will be described later together with that of the mastoid portion.

Mastoid portion

In modern man the mastoid portion consists of two parts, a larger and more protuberant anterior one, represented by the mastoid process, and a smaller, flatter, posterior one which has a squama-like character similar to the squamae temporalis and occipitalis. Concerning their topographical relation to the squamous and petrous portions both parts lie to the rear of the latter but the protuberant one generally below the squamous portion if the supramastoid crest is taken as level. In anthropoids there is only one undivided mastoid portion situated behind the squamous portion, in orang-utang and gorilla even high above the level of the supramastoid crest. There still is another difference between man and anthropoids. In the former the protuberant part can be subdivided into two portions, an upper and a lower one. The lower one, the mammillary process, projects freely downward while the upper one merely represents its base and extends upward to the supramastoid crest. In anthropoids, a free process is lacking; instead the entire portion bulges laterally and carries on its surface a broad-rooted ridge which continues posteriorly into the nuchal crest.

Sinanthropus exhibits in general the human type of the mastoid portion. There are the two parts, the anterior protruding and the posterior flat one, their respective extension being indicated by the incisura parietalis. The protuberant part lies below the level of the supramastoid crest but extends more backward than in the average modern man. In addition, there is one rather significant difference. In modern man the entire mastoid process descends almost perpendicularly, if the skull is orientated in the Frankfort plane; at best its axis deviates slightly medianwards. In *Sinanthropus* the protuberant part appears as an outward bulge of the cranial surface while the free projecting mammillary process bends distinctly inwards (cf. all the occipital views of the *Sinanthropus* skulls—Figs. 23; 52, 58; 64, 70; 76, 82).

As to the form and size of this free portion, great variability exists in modern man. In some cases the mammillary process is very small; this means that its longitudinal diameter measured from the porus acusticus to the posterior end of the digastric fossa is short and so is the vertical diameter measured from the supramastoid crest to the tip of the process. In other cases these diameters are much larger. Evidently sexual differences exist: females in general have smaller processes than males; but apart from sex, small and large ones can be found within one and the same population or also in different racial groups. In all of the *Sinanthropus* specimens the free portion of the process is completely broken off or damaged. Nevertheless, it is possible to estimate the size of this portion. In so doing, however, one point must be taken into consideration. In modern man the process is convex at its lateral surface while the medial surface appears as if the digastric fossa had flatly cut off the medial half; in addition, as mentioned above, the process descends almost perpendicularly. Under these conditions even a strongly projecting process, if broken at its base, may appear to be small. In *Sinanthropus*, however, where the mastoid process rather represents a part of the cranial surface itself even a slightly projecting mammillary process may appear large if the surface is worn off. In the juvenile *Sinanthropus* Skull III (Figs. 103 and 104, pm) the free portion of the process was small and the same is true of Skull XI (Fig. 110, pm). But in all of the other cases: Skull V (Figs. 26, 30), Skull X (Fig. 108), Skull VII (Fig. 112) the process was large. How far it projected is difficult to judge because of its particular orientation to the cranial wall, as discussed above.

But it is not too much to assume that there was a fairly far projecting process, not decisively smaller than in modern man. How easily one may be mistaken in this respect is shown by the *Pithecanthropus* skulls. In *Pithecanthropus* Skull II the region of the mammillary process is slightly worn off. In his first publication (1938) on this specimen von Koenigswald claimed complete absence of the mastoid process and deduced from this presumed particularity that *Pithecanthropus* had to be considered a very primitive hominid. von Koenigswald is wrong, however. *Pithecanthropus* Skull II had a mammillary process (cf. Weidenreich 1940b; Figs. 12 and 13) though it projected but slightly beyond the level of the base. That this peculiarity however, does not indicate a specific character valid for the type as such follows from the appearance of *Pithecanthropus* Skull IV. This specimen, obviously a male, exhibits a well developed and far-projecting mammillary process (Fig. 230). The relative smallness of the process in the two *Sinanthropus* Skulls III and XI is thus due to the youth of the first case and the female sex of the second. The characteristic features of the mastoid process in primitive hominid types known hitherto consist less of the smallness of its mammillary process than of its orientation to the vertical axis.

The lateralwards bulging of the protuberant part of the mastoid portion of the *Sinanthropus* skull is still more accentuated by the development of the mastoid crest the nature of which was discussed in a previous publication (Weidenreich; 1940b). Corresponding to the strong development of this crest combined with that of the supramastoid crest the supramastoid sulcus, that is the depression between them, is well pronounced and relatively deep in *Sinanthropus*.

The same variability which characterizes form and size of the mastoid process applies to form and size of the digastric fossa (incisura mastoidea). In modern man the fossa can be so narrow that it merely looks like a cut, while in other cases it may appear as a wide and flat groove. In *Sinanthropus* Skull V it is cut-like on the right side (Fig. 30, im) but wide, flat and low on the left (Fig. 26, im). There also is a difference between the two sides in Skull III: on either side the fossa is wide and long, but toward its posterior extremity it becomes slightly narrower on the right side (Fig. 103, im), while it widens considerably on the left (Fig. 104, im). Such widening is particularly pronounced in Skull X (Figs. 56, 60 and 108) where the posterior extremity of the fossa opens widely like a fan. In Skull XI the fossa as a whole is very wide but much more so on the right (Figs. 68 and 72) than on the left side (Figs. 67, 72, 110). In this skull it is lengthwise partitioned into two grooves, an anterior and a posterior one; on the right they are of equal width while on the left side the anterior one is distinctly narrower than the posterior one.

Although there is no essential difference in the general character of the digastric fossa between *Sinanthropus* and modern man—except perhaps that the narrow type is more frequent in the latter,—a greater divergence exists in the appearance of the structure lying between tympanic plate, mammillary process and occipital bone, differences which are apparently a consequence of the reduction and altered orientation of tympanic plate and pryamid, as discussed above. In modern man the foramen stylomastoideum is situated at the bottom of the funnel-like pit from which the digastric fossa ascends directly opposite to the styloid process. Styloid process, foramen stylomastoideum and fossa are arranged within a straight line running obliquely from front medially to back laterally. In *Sinanthropus* the foramen processus styloidei which takes the place of the absent process, and the digastric fossa are also arranged within a straight line but the foramen stylomastoideum lies outside it. In addition, instead of a funnel-like pit a saddle-like elevation intervenes between the anterior entrance to the fossa and the

area of the foramen stylomastoideum which abuts against the medial slope of the mastoid process. The digastric fossa begins behind this elevation, in other words, it is situated posterior to the process but not medial thereto (cf. Figs. 26, 112; im). In case the mammillary process is broken off, the horizontal section reveals its form as a triangular one with its apex pointing medialwards. In modern man the section is elliptical with the long side turned medialwards.

The median side of the digastric fossa in *Sinanthropus* is formed by a high and rough crest-like elevation varying somewhat in width. The crest runs along the occipitomastoid suture partitioning it into a mastoid and occipital portion. This crista occipitomastoidea is well developed in all of the *Sinanthropus* specimens (Figs. 24–26; 54, 60; 66, 72; 78, 84; 103) and, therefore, must be considered a characteristic feature. In modern man the area in question shows great variability; in most cases the crest is only slightly developed, so that it escaped the attention of the authors and remained unnamed. Only Henle (1871) says: "the digastric fossa is bounded medianward by a low, sharp or obtuse crest that runs parallel to the mastoid process."

In anthropoids the equivalent to the mastoid process consists either of a small prominence at the lateral half of the basal surface of the generally bulging mastoid portion as in gorilla (Fig. 123, pm) and orang-utang, or of a large and low transverse tuberosity in the same place as in chimpanzee (Fig. 122). On the other hand, there is a well developed occipitomastoid crest marking the medio-posterior margin of the mastoid portion. This crest occasionally surpasses the mastoid process in height. In other cases it is replaced by a low, indistinct swelling that may even extend medially up to the occipital condyle. But regardless of the individual shaping of this rather variable region, it can be considered an almost constant occurrence that the surface of the mastoid portion between the lateral prominence and the medial crest represents a smooth longish depression; it sometimes deepens to a relatively narrow groove, and then again to a broad and shallow one without making the impression of a special feature. This area, undoubtedly, is the equivalent to the human incisura mastoidea; its variability involves all three anthropoids alike, no particular variation being confined to gorilla or chimpanzee, for instance. It may even happen that there is no depression at all between the mastoid process and the occipitomastoid crest, instead these two formations join one another so closely as to make the crest appear merely as the medial margin of the mastoid process.

The striking difference in the appearance of the mastoid portion in man, *Sinanthropus* and anthropoids proves that the transformation of the region must be regarded as the effect of a more general stimulus. The shaping of these special features cannot be the result of localized forces. Anatomists always supposed causal relation between the incisura mastoidea and the posterior belly of the digastric muscle; this is the reason why the incisure has been called "digastric fossa," and indeed in most cases of modern man the muscle emerges directly from the incisure. But, according to Eisler (1912), the origin can extend to the medial side of the mastoid process in case the incisure is narrow; occasionally it even reaches the lateral portion of the superior nuchal line. As to the exact localization of the origin of the muscle in anthropoids very little is known; the usual remark that the origin of the muscle is the same as in man does not mean much if the entire region differs in its structural character.

With regard to this region *Pithecanthropus* reveals a more primitive character than *Sinanthropus*. In Skull II as well as Skull IV the incisura mastoidea represents a wide and shallow depression which recalls the conditions of gorilla and orang-utang. While *Pithecanthropus*, however, follows the human line in the general shaping of the mastoid portion *Paranthropus* shows a distinct simian character.

Whether the sulcus arteriae occipitalis, a rather constant feature of modern man, is developed or missing in *Sinanthropus* cannot be decided because of the inadequacy of the material at hand. In all of the available specimens, with the exception of Skull III, the cranial base is broken off just along the occipitomastoid suture. On the left side of Skull III the nuchal planum adjacent to the mastoid portion is preserved but the conditions are obscure, for the occipitomastoid suture which supplies the bed for the sulcus in modern man gapes widely. It may be surmised that this fissure served as passage for the artery and consequently corresponds to the sulcus. At any rate, the preserved mastoid section of the occipitomastoid crest does not display in any other instance an indent that could pass for a vascular sulcus.

Two other features which deserve mentioning remain though they do not differ from conditions in modern man, namely the foramen mastoideum and the persistence of the sutura squamosomastoidea. The foramen mastoideum is present in Skull III—right side (Fig. 101), Skull V—left side (Fig. 24), Skull X—right side (Fig. 107), Skull XI—left side (Fig. 109). In all these cases the foramen is situated above the superior extremity of the incisura mastoidea and close to the occipitomastoid suture. In Skull III (left), Skull XI (right), and Skull XII (left) a foramen is not recognizable but it may have happened that the foramen was embedded in these cases within the occipitomastoid suture which is not completely preserved in all instances. Vestiges of the sutura squamosomastoidea are present in Skull XII (Figs. 73 and 79); they occupy the same place as they do in modern man, namely coursing along the mastoid portion near its posterior boundary.

Although not strictly a part of the mastoid portion it is appropriate to refer here to a variation rather frequently found in modern man, namely the spina supra meatum. Where the sulcus supramastoideus or the depression between the supramastoid and mastoid crests turns toward the entrance of the auditory meatus modern man has, on the side of the supramastoid crest, a peculiar structure. This consists of a small bony crest which looks as if it were split from the wall behind, and of a narrow cleft separating the crest from the wall. This formation is called the "suprameatal spine." It is found in all races of mankind although it may be absent in a percentage of each race. Sometimes its presence is indicated by a tiny elevation only with an equally small depression behind it, sometimes by only one of these structures. In no case, however, has the feature the appearance of a "spine" as its name suggests, and, according to some authors, it is more frequently found in males than in females. In *Sinanthropus* the typical suprameatal spine is absent in all cases where this region has been preserved. In Skull III (both sides), Skull V (left side) and XI (both sides) there is neither an elevation nor a pit. On the right side of Skull V (Figs. 28 and 29) there is an injury near the spot under discussion which has exposed a mastoid cell, and, in addition, the surface above this hole is eroded, but neither irregularity of the surface can be taken as an indication of the spine. Nor can they conceal the spine's presence since both are clearly situated below the usual seat of this structure. In Skull X there is a fine, low, stroke-like structure with a small depression behind it which might pass for a faint suprameatal spine. (The photograph, Figure 50, gives the impression that there is a big elevation at the seat of this spine but this is a false impression due to high lights which fell at this point.) In Skull XII (Figs. 73 and 79) there are two irregulate indentations at the seat of the spine and it is not possible to decide whether these are natural or artificial. In any case, they differ from the usual appearance of the spine to such an extent that I do not consider them as the same feature or as equivalent to it.

As to *Pithecanthropus*, the surface of the skull is slightly eroded in some places which renders it difficult to decide whether the unevenness is artificial or natural. On the right side of Skull II there is certainly nothing like a spine; on the left the surface is a little desquamated but apparently no spine-like formation existed. The right side of Skull IV exhibits a nodule—like a small pin-head—at the typical site of the spine while the left side is damaged. The condition of *Homo soloensis* in this regard has to be checked on the originals. In Skull V a spine is absent. The same seems to be the case in the Rhodesian skull. The rest of the Neanderthalians, except Spy I, show typical spines. In the anthropoids the spine is absent. The surface of the bone in the region under discussion is frequently rough, and the excrescences sometimes take the character of exostoses. Whether these formations correspond to the human suprameatal spine, however, can only be found out through special investigations. So far as I know, nothing is known about the significance and origin of the spine in man. In any case, even if the doubtful instances are counted as positive, spines like those found in modern man or in Neanderthalians do not occur in *Sinanthropus*, *Pithecanthropus* and *Homo soloensis*.

Internal Surface of the Temporal Bone

As the internal surface of the squamous portion has already been described above I can confine myself to the description of the internal surfaces of the petrous and mastoid portions.

The squamous portion of the temporal bone is remarkable by its thickness which is manifest not only in accidental fractures but also on separate bones where intact sutures are exposed. As to the tympanic plate and the petrous portion, it was already pointed out above that these bones considerably exceed in general size and robustness all known human bones of this kind.

The extraordinary thickness of the mastoid portion can best be illustrated by recording the diameter of the sutura parietomastoidea measured just in front of the asterion and behind the incisura parietalis as listed in Table XV. This region corresponds to the upper part of what I

TABLE XV

Thickness of the Mastoid Portion (in mm.) Measured on Separate Bones, of Sinanthropus and Modern Man

Location of measurement	Sinanthropus					Modern man
	III		V		XII	
	r	*l*	*r*	*l*		
Sutura parietomastoidea behind incisura parietalis	15	18	15	17	15	3.5–7
Sutura occipitomastoidea medial to mastoid process	6.5	7	7.5	8	—	3–6

termed the squamous portion of the mastoid. From the figures it follows that the mastoid portion of *Sinanthropus* is three to four times thicker than that of modern man where the bone is thickest, and more than twice where it is thinnest. A direct comparison with anthropoids is difficult because of the particular development of the mastoid portion in apes. As mentioned above, almost the entire portion is inflated by a high pneumatization which extends over a much larger area than it does in man. This is especially true of the male gorilla. In female individuals and in both sexes of the chimpanzee where the pneumatization is considerably less pronounced or entirely missing the bone is thick but does not reach such proportions as in *Sinanthropus*. The interpretation of these features will be given in the chapter dealing with the architectonic structure of the skull.

The most striking difference displayed by the pyramid of *Sinanthropus*, when compared with that of modern man, is in size and form.   There is, of course, a considerable variation in man and partly also in *Sinanthropus*, but considered as a whole the pyramid of the latter is much stouter and does not appear as slender as in most cases of man.   This difference is mainly due to the fact that in man (Fig. 130) the posterior surface of the pyramid forming the anterior wall of the posterior cerebral fossa not only slopes almost vertically but rather frequently also shows, particularly in its lateral part, a deep impression undermining more or less the margo superior (ms) while in *Sinanthropus* the posterior surface slopes more gradually (Figs. 22 and 27).   The same holds good, though to a lesser extent, for the anterior surface.   In other words, in modern man the margo superior is mostly a sharp edge which partly overhangs the posterior surface whereas in *Sinanthropus* it is an obtuse or completely rounded corner with both of the adjacent surfaces pressed down toward the floor of the fossa.   This difference in form turns a sagittal section through the middle of the human pyramid into a high and narrowly based triangle while it is low and broad in *Sinanthropus*.   The height of the posterior surface of the *Sinanthropus* pyramid, measured near its base from the superior border of the sigmoid sulcus to the sulcus petrosus superior, exceeds 18 mm. in no case while in modern man it may reach as much as 23 mm.   Figure 27, for instance, which depicts the interior surface of the left temporal bone of Skull V, shows the entire medial portion of the pyramid to be broken off, thereby exposing an almost cross section through it.   The distance between the points where the anterior and posterior surfaces of the pyramid meet the floor of the medial and posterior cerebral fossae is much greater in *Sinanthropus* than in man.   Moreover, in this instance the distance in question is much greater than in any case of modern man because of the extraordinary size of the *Sinanthropus* pyramid as a whole which, according to my knowledge, is only surpassed by the pyramid of *Pithecanthropus* Skull IV (Fig. 244).

The extraordinary size of the pyramid in proportion to the roominess of the cranial cavity and its lowness and flatness when compared with modern man is undoubtedly a simian character.   In anthropoids (Figs. 131 and 132), particularly in gorilla (Fig. 131), the pyramid seems flat and pressed against the floor over a considerable distance.   This different appearance can be traced back to the same factor which is responsible for the change in the structural character of the pyramid and in the orientation of the tympanic plate described above, namely to the rolling-up of the cranial base which in turn caused a lift of the pyramid toward the interior of the cranium and at the same time a shortening of its sagittal extension.

The anterior surface of the *Sinanthropus* pyramid is flatter and extends further forward than in modern man, as already stressed above.   Another difference concerns the distinctiveness of its relief.   In modern man the eminentia arcuata (Fig. 130; ea) is usually well developed and the area of the tegmen tympani as well as that behind the eminentia clearly depressed.   In *Sinanthropus* (Figs. 27, 100; ea) this unevenness is much less pronounced, thus bearing a greater similarity to the conditions in anthropoids where the anterior surface is almost smooth.

That the margo superior is rounded and not edged as in man has already been mentioned.   The greatest differences, however, are revealed by the posterior surface.   As far as I was able to ascertain, Schwalbe (1902) was the first and only author who recognized that the cerebellum partakes in its special figuration.   He omitted to go into details and confines his remarks to the statement that an anterior surface of the cerebellum produces a special "planum" at the posterior surface of the human pyramid.   This planum occupies the lateral area between the porus acusticus internus or, more correctly, the apertura externa aquaeductus vestibuli and the sig-

moid sulcus. There is no doubt that such a "planum" is a regular occurrence in man but as a matter of fact in the overwhelming majority it is not a planum but rather a fossa (Fig. 130) which occasionally reaches considerable depths and often includes also the sigmoid sulcus. It is especially found where the sulcus is wide and deep; in all those cases the margo superior overhangs this region so that it appears as a more or less sharply projecting edge and the fossa beneath as a distinct "impressio cerebellaris."

In *Sinanthropus* these conditions are somewhat different. In some cases the "planum" is developed but occupies a much smaller area and is, if at all, only slightly impressed. Then again, there is neither a planum nor a fossa and instead the surface bulges backwards. Similar conditions are found in anthropoids; in no instance is there such a large and deep impressio cerebellaris as is seemingly characteristic of modern man.

As to other features of the posterior surface the only noteworthy difference between *Sinanthropus* and modern man concerns the apertura externa aquaeductus vestibuli. In the latter this slit opens into the impressio cerebellaris and the part covering the slit projects more or less forming thereby the anterior boundary of the impressio. In *Sinanthropus* Skull V (Fig. 27; av) and all the other adult specimens (right and left side) the cover of the aperture appears as a distinct eminence and the slit opens into a recess situated beneath the eminence. Only the juvenile Skull III shows conditions similar to that of modern man. · The porus acusticus internus (pai), the fossa subarcuata, and the apertura externa canaliculi cochleae (acc) are like such structures of modern man. The sulcus petrosus superior is only developed near the base of the pyramid; it represents a relatively wide but short furrow in Skull III (left side) and Skull V (left side; Fig. 27) while it is only faintly indicated in Skull III (right side), Skull X (right side) and Skull XI (left side). In Skull V (right side), Skull XI (right side) and Skull XII (right side) the sulcus is absent.

The sulcus sigmoideus displays the same variability as in modern man. In Skulls III, V (Fig. 27), and XI where both sides are preserved it is wider and deeper on the right side; in Skull X (right side) and Skull XII (left side) the sulcus is wide and deep. In no instance, however, does the sulcus match the depth and width of that of modern man.

In discussing the internal surface of the parietal bone, attention has already been drawn to the special structure of the Sylvian crest which forms a definite superior boundary of the middle cerebral fossa almost completely wanting in modern man. As the squama of the temporal bone as a whole is very low, that portion of the fossa which is enclosed between crest and pyramid and contains the greater part of the temporal lobe appears much more compressed and more distinctly demarcated from the rest of the pallium than in modern man (cf. Figs. 22, 27 and 95).

Sphenoid bone

Of the sphenoid bone of *Sinanthropus* very little is preserved. The fragments are chiefly confined to the greater wing and the base of the pterygoid process, with the exception of Skull II (Figs. 5–8; 11–14, 16) where the wing is pretty well intact, whereas in all of the other cases: Skull III (particularly left side), Skull XI (left side; Figs. 61, 66, 67, 69, 72) and Skull XII (left side; Figs. 73, 78, 79, 84) only smaller parts are preserved. The lateral part of the lesser wing where it joins the margo frontalis of the greater wing is preserved on the left side of Skull III and the base of the pterygoid process in Skull II (Figs. 11–14, 16).

The general form of the *Sinanthropus* sphenoid does not diverge essentially from that of modern man, nevertheless shows certain characteristic differences in details.

As is evident from Skulls II (Fig. 11) and III the length (sagittal direction) of the greater wing as a whole is not shorter than in man but the upper and posterior portion is; this takes

part in the formation of the pterion. Although the pterion fails to display the anthropoid pattern (contact of frontal and temporal bones) in any of the cases, as was already discussed above, the distance between these two bones is rather small and certainly much more so than is the rule in modern man.

One of the most conspicuous differences concerns form and orientation of the facies temporalis and infratemporalis. In modern man the facies infratemporalis is horizontally oriented while the facies temporalis stands almost vertical; the two facies are therefore bent toward one another. The bend may be a sharp one, as is usually the case, or the passage may be more gradual; in the first case the bend is accentuated by the development of a more or less pronounced crest, crista infratemporalis, which marks also the boundary between the two facies. When such demarcation is wanting the region where the margo zygomaticus reaches the fissura orbitalis inferior and continues into the crista orbitalis and crista sphenomaxillaris, respectively, is marked by a distinct tuberosity (spina infratemporalis) with one, two or even several edges or pointed spines.

In *Sinanthropus* Skull II no sharp bend exists but rather the facies temporalis passes gradually over the facies infratemporalis (Figs. 11 and 16); both of the surfaces thus represent a rather flat and continuous curve while the crista infratemporalis is merely indicated by a slightly elevated line. The spina infratemporalis consists of three moderately developed edges which follow each other from above downwards. The lowest one lies somewhat below the level of the crista orbitalis (cob). In a diagram of the outline of the lateral surface, drawn approximately in frontal plane (Fig. 133, C), the facies temporalis curves slightly outwards and the facies infratemporalis slightly inwards. Since the very same conditions exist in *Sinanthropus* Skull XI (Figs. 67 and 72) in which only the posterior half of the lateral surface of the greater wing is preserved, it seems justified to assume that the feature in question is characteristic of *Sinanthropus*. This is all the more noteworthy since the Ehringsdorf Skull belonging to the Neanderthal group presents the same peculiarity in contrast to the Rhodesian and Gibraltar Skulls which show the type prevalent in modern man. The two types also occur in anthropoids with the interesting difference that the first human type characterized by a sharp bend predominates in chimpanzee (Fig. 133, D) while the second type with the facies infratemporalis curved only slightly inwards seems to be specific of orang-utang and gorilla (Fig. 133, A, B).

Yet another peculiarity deserves mentioning. In great apes the facies temporalis extends downwards to a much lower level than the entrance to the inferior orbital fissure. This is especially pronounced in gorilla and orang-utang where, in addition, the facies approaches the maxilla so closely that the lower orbital fissure is reduced to a mere slit and the orbit remains accessible only from below. In man the facies temporalis usually terminates more or less above the floor of the orbit so that the inferior orbital fissure represents a wide cleft which makes the orbit directly accessible from the side. Neither the floor of the orbit nor a maxilla connected with the calvaria is preserved in *Sinanthropus*. Such being the case, it is impossible to determine which of the conditions mentioned before existed in this hominid. However, there is an indication that *Sinanthropus* followed the anthropoid line to some extent. The crista orbitalis (Fig. 13; cob) which marks the lower boundary of the facies orbitalis and thus the level of the floor of the orbit runs somewhat at a higher level than the crista infratemporalis while in modern man the two crests are usually situated within the same horizontal plane. It seems, therefore, that the inferior orbital fissure was a narrow cleft in *Sinanthropus*, situated slightly below the floor of the orbit. This peculiarity fits in well with the supposed shortness of the su-

perior orbital fissure (see above and Fig. 84; fos). On the left side of Skull III the fragment of the lesser wing joins the anterior margin of the greater wing to a much greater extent than is the rule in modern man; in other words, the lateral portion of the superior orbital fissure, formed exclusively by the two wings, appears so small in *Sinanthropus* that the fissure consists chiefly of the medial portion, which is bounded medially by the body of the sphenoid and laterally by the basis of the greater wing. These are exactly the conditions of the anthropoids, especially of gorilla, where occasionally the fissure is not much larger than the optic foramen (Fig. 245, C). In contrast to modern man with his distinct trend toward an "open" orbit, that is, to widen the fissures, *Sinanthropus* approaches the anthropoids and all the platyrrhines and catarrhines with their "closed" orbits.

It is of great interest that the Rhodesian Skull shows a typical gorilla pattern (Fig. 245, D). Not only is the superior orbital fissure confined to the medial section and thus not much larger than the optic foramen, but also the inferior fissure is reduced to a narrow slit opening downwards into the infratemporal fossa, a consequence of the large orbital facies of the sphenoid and its descent below the level of the orbital floor. The orbit of the Rhodesian Skull, thus, is an excellent example of a "closed" orbit in fossil man.

The facies orbitalis a large part of which is only preserved in Skull II (Fig. 12) shows no noteworthy peculiarities. Yet I have the impression that the facies is higher and longer than is usual in modern man; since, however, only one *Sinanthropus* specimen is available and, on the other hand, the number of appropriate comparative human material at my disposal is small I do not venture to claim that the described form is characteristic of *Sinanthropus*. The crista orbitalis is developed (see above), and there is also a distinct spina musculi recti lateralis of the same size, form and location as in modern man.

The facies cerebralis of the sphenoid (Fig. 234, A), however, presents quite a different aspect when compared with man. One of the most striking differences is the small size of the facies in transverse direction and, consequently, the lowness of its vertical direction. The extension of the arc of the facies measured from the foramen rotundum to the sutura sphenoparietalis measures 36 mm. in Skull II and 43 mm. in Skull III while it reaches 50 mm. and more in modern man. This smallness of the facies is due to the development of the crista Sylvii on the internal surface of the sphenoid angle of the parietal bone which not only projects into the cranial cavity but also continues into the parietal angle of the sphenoid, and transforms the suture into such a distinctly squamous one as those of the parietal and temporal bones.

Another peculiarity of the facies cerebralis concerns its configuration. In modern man the facies consists of a widely curved cavity supplied with impressions and juga and partly roofed by the projecting edge of the lesser wing (Fig. 130, map). In *Sinanthropus* the cavity is restricted to a low but deep niche without special relief (Fig. 234, A). This feature seems typical since it is found in all of the specimens in which even only a part of the facies is preserved, and, furthermore, it fits in with the picture of the whole middle cerebral fossa described above. In addition, the same conditions are found in the Ehringsdorf skull; my description of the region in question (1928) reads as follows: "The facies cerebralis of the greater wing is represented by an oval, narrow, deep, regular fossa that rather has the aspect of the socket of a joint; a special relief is not recognizable. In the Gibraltar and Galilee skulls the facies is much wider and shallower resembling more that of modern man."

In the above discussion of the particular development of the crista Sylvii and form and size of the middle cerebral fossa I already called attention to the fact that we are dealing here with

a specific hominid character which can hardly be traced back to the anthropoids. The same holds good for the configuration of the facies cerebralis. In gorilla a special concavity is completely wanting, so is the Sylvian crest and the overlapping of the lesser wing (Fig. 131); in chimpanzee the concavity is only faintly indicated (Fig. 132), but it is more pronounced in the orang-utang.

An additional peculiarity of the *Sinanthropus* sphenoid concerns the thickness of the greater wing. In modern man the entire bone appears completely compressed and the wall between the three facies rather thin, especially toward the margins. Figure 134 demonstrates these conditions as shown by a cross section through the greater wing of a European skull oriented in horizontal plane. In *Sinanthropus*, however, the bone is much more robust and does not show such a tapering toward the margins. This is especially true of the margo squamosus between the facies temporalis and cerebralis; in man the edge scarcely reaches a thickness of 1 mm. while in *Sinanthropus* it amounts to about 8 mm. In orang-utang the robustness of the sphenoid is rather similar to that of *Sinanthropus* (Fig. 134). The robustness of the *Sinanthropus* sphenoid is in accordance with such of other cranial bones and has to be considered a characteristic feature of the prehominids (see later).

The roots of the greater wing and the base of the pterygoid process are preserved in Skull II only (Figs. 13, 14 and 16, pp). But there are no specific differences in structures as the foramen rotundum (fr), the anterior rim of the foramen ovale (fov), or the lateral rim of the canalis pterygoideus (cp), when comparing *Sinanthropus* with modern man. Yet it is interesting to note that the broken-off root of the pterygoid process shows no indication of the sinus sphenoidalis having extended into the root as in *Pithecanthropus* Skull IV where the entire root is hollowed. The hollowing of the base of the pterygoid process is characteristic of anthropoids. According to Cope (1917), such a lateral recess of the sphenoidal sinus occurs even in 25 per cent of modern man; I (1928) observed its presence in the Ehringsdorf and Galilee skulls, and a sinus also exists in the Rhodesian skull. Its absence in *Sinanthropus*, in spite of the extreme thickness of the cranial bones, conforms rather well to the absence or poor development of the frontal sinus as stressed above. I shall return to this question later.

II. Facial Skeleton

1. Nasal Bone and Nasal Bridge Portion of the Maxilla

Only very little of the nasal bones and the nasal bridge is preserved in *Sinanthropus*. Yet since this comprises the entire superior parts with the nasofrontal suture and the frontal process of the maxilla backward to the lacrimale, it is sufficient to permit the construction of a fairly accurate picture of the general shape of the nasal bridge and the nasal saddle.

The nasofrontal suture is completely preserved in Skulls III, X (Figs. 51 and 57) and XII (Figs. 75 and 81) and partly so in Skulls II (Figs. 7 and 13) and XI (Figs. 63 and 69). In all these skulls, this suture together with the frontomaxillar suture takes a continuous, horizontal course: The same course is evident in the Rhodesian Skull while in the European Neanderthalians (Neanderthal, Spy, La Chapelle-aux-Saints, Krapina) the suture more or less ascends toward the midline or seems interrupted because the nasal bones extend further upward than the frontal process of the maxilla. After Le Double (1906) and R. Martin (1928) both variations occur in modern man but, according to the latter author, the first one more among Mongols and Negroes and, according to the former, the second one more among Europeans.

In Skull XII the two nasal bones are in junction with each other, with the frontal bone and with a small fragment of the right frontal process of the maxilla (Figs. 79, 80, 81, 84). The superior parts are complete but the lower ones are broken off. Since, however, the frontal process of the maxilla—probably that of Skull X—is preserved almost in its entire length (Figs. 135, 136), the lateral length of the nasal bone can be estimated; I computed it to be 23 mm. The upper breadth of the two nasal bones (at the level of the nasofrontal suture) is rather considerable, measuring 17.3 mm. in Skull XII. That this is not an individual case can be deduced from Skull II in which, although the preservation of the superior portion of the nasal bones is not as complete as in Skull XII (Figs. 11, 12, 13, 16), the upper breadth was certainly not less than 17 mm. In Skull III in which the nasal bones are lost but the nasofrontal suture preserved the breadth is the same. The least breadth cannot be determined with absolute certainty on account of the defective conditions of the bones at hand, but there can be little doubt that the least breadth was not essentially smaller than the upper one. This follows from Skull II (Fig. 81); In all human and anthropoid nasal bones which narrow toward the middle the diminishing already sets in very high up. In Skull II, however, there is no indication of a clear diminution although the length of the nasal fragment amounts to 13–15 mm.; on the contrary, the lateral margins of the two bones take a fairly straight course. Although the lower extremities of the nasal bones are missing, it is possible to discern whether and to what extent the extremities widen toward the apertura piriformis. The margo nasalis of the frontal process of the maxilla, already referred to (Figs. 135 and 136), runs from above laterally downward and medially. Even conceded that the upper end of the nasal margin was damaged, the size of the possible defect is not of such an entent as to permit a considerable breadth of the lower extremity of the nasal bone. That the width slightly increased toward the end can be deduced from the form of the curvature the contour of the nasal bridge presents when drawn in profile (Fig. 137).

With the breadth of 17.3 mm. at the upper end, a least breadth of the same extent, and a lateral length of 23 mm. the *Sinanthropus* nasal bones fall far beyond the average range of the bones of modern man. In Table XVI the measurements of the *Sinanthropus* bones are listed

TABLE XVI

Measurements of Nasal Bones of Sinanthropus and Various Races of Modern Mankind

	Breadth		Lateral Length	Author
	Upper	Least		
Krapina	20.5(?)	18.0	—	Gorjanovič-Kramberger (1906)
Sinanthropus	17.3	c.17.0	23.0	Weidenreich
La Chapelle-aux-Saints	14.0	14.0	29.0	Boule (1911)
European	12.8–13.5	9.4–10.6	23.6–26.8	⎫
Negro	12.2	8.7	24.6	⎬Manouvrier (1893)
Melanesian and Australian	11.1–11.8	8.9– 9.2	22.0	⎪
Mongolian	8.2–11.1	5.4– 8.3	23.6–26.9	⎭

together with those of various races of modern mankind; the figures show that the nasal bones of *Sinanthropus* are much wider than the average of the latter. According to Manouvrier (1893) individual maximum values of the upper breadth of more than 17.3 mm. occur only in European and Negro, while a maximum value of 17 mm. for the least breadth has been found only in

Basques. As to the breadth-length index (upper breadth and lateral length) *Sinanthropus* with an index of 75.2 is only surpassed by Negroes and Melanesians according to figures given by the same author. The extraordinary breadth of the *Sinanthropus* nasal bones corresponds to that of the Neanderthal man. Boule (1911) computed the upper and the least breadth of the nasal bones of the skull of La Chapelle-aux-Saints at 14 mm. Gorjanovič-Kramberger (1906) records the least breadth of the Krapina remains to be 18 mm., thus the upper breadth must have been even more than in *Sinanthropus*. Pycraft (1928) gives no figures of the breadth of the nasal bones of the Rhodesian Skull; he confines himself to the remark that the bones "are broad, but not excessively so."

One of the most characteristic features of the *Sinanthropus* nasal bone is that there is practically no difference between the upper breadth and the least one which usually is found within the upper moiety of the bone. Only very slight contraction occasionally also occurs in modern man; R. Martin (1928) states: "Broad nasal bones with small difference between upper and middle breadth is most frequently found among Mongols." Anthropoid nasal bones differ widely in form as well as proportions from *Sinanthropus*, with the exception of those of the chimpanzee which show some resemblance.

Although the anthropological literature contains numerous statements about high and flat nasal bridges, no worker, not even Le Double (1906) who devoted many pages of his book to the variations of the nasal bones, has hitherto taken the trouble to define exactly what particular structure of the nasal skeleton causes the former or latter appearance. In order to understand the characteristic structure of the nasal bridge of *Sinanthropus* it is, therefore, necessary to make some introductory remarks. The nasal bridge is called high if the midline of the saddle of the bridge which in general coincides with the internasal suture is well above the base of the bridge or, in other words, above a frontal plane laid through the two anterior lacrimal crests. The bridge is flat if the distance between the midline and base is short. The bridge itself is formed by the two nasal bones and the two bridge portions of the maxilla which are bound by the nasomaxillar margin, on one side, and the crista lacrimalis anterior, on the other. Height and lowness of the saddle depend upon two factors: first on the breadth of the individual bones and second on the position in which they are placed to one another. This can best be illustrated by a cross section through the saddle when the skull is oriented in norma verticalis as given in Figure 135. *A* represents the flat saddle arch of a female Siamese; in this case the four bones form a round arch. *B* represents the high saddle arch of a male Hungarian; in this instance the bones form a pointed arch, the median margins of the nasal bones rising to a sharp ridge along the internasal suture. However, this ridge is not necessary for the formation of a high arch. The nasal bones, for instance, can be erect but rounded off at the suture itself; there are also other possibilities which may be omitted since this is not the place to discuss further details.

If one attaches special value to expressing the height of the saddle arch by indices; an index can be derived by taking the distance between the two cristae lacrimales anteriores as basal breadth of the arch and the perpendicular drawn from its vertex as height. This height-breadth index is low the flatter the arch and high the higher the arch; in case *A* of Figure 138 the index is 30.1 and in case *B* 44.1.

In *Sinanthropus* Skull XII the saddle arch is broad and relatively high, its index being 37.0; but the arch is rounded, the nasal bones and the bridge portions of the maxilla forming a continuous curved line (Fig. 139 A). Such arrangement of the constituents of the arch is characteristic of all preserved nasal bridges of the Neanderthalians: Rhodesian (Fig. 139 B), Gibraltar

(Fig. 139 C), and Krapina C, though the arch of the Gibraltar Skull, so far as the corrosion permits an exact determination of the landmarks, seems higher (height-breadth index: 43.4) than that of *Sinanthropus* and the Rhodesian Skull (index: 39.3).

In anthropoids the nasal bridge is broadest in gorilla (Fig. 140 A) and narrowest in orang-utang (Fig. 140 C). In the latter case the narrowness is due to a progressive reduction of the nasal bones which may reach such a degree as to cause complete disappearance so that the bridge portions of the maxilla meet one another directly in the midline. The gorilla differs again from orang-utang and chimpanzee; the medial margins are bent upward, thus forming a rather sharp ridge along the internasal suture (Fig. 140 A), and so recalling conditions occasionally found in modern man. The height-breadth index of the nasal arch is very low in anthropoids; in the specimen illustrated in Figure 137 the index of the gorilla is 24.9, that of the chimpanzee 25.8, and that of the orang-utang 14.5. This is considerably less than in modern man and also less than in *Sinanthropus* and the Neanderthalians.

The profile of the *Sinanthropus* nasal bridge shows a continuous curvature (Fig. 141 A). Since the lower extremities of the nasal bones are not preserved it cannot be stated that the missing ends finally bend inward as is usual in modern man. However, as only a short piece is broken off and the remaining part fails to indicate any tendency toward bending inward, it is safe to assume that the bones kept their curving down to the aperture. Such continuous curving is also found in Neanderthal Skulls (Fig. 141, B–D). Only in the La Chapelle-aux-Saints Skull (Fig. 141, E) in which the nasal bones themselves are not preserved but merely the bridge portions of the maxilla the concave outline seems to have altered into a convex one. Hans Virchow (1912) has taken profile contours of the nasal bridge of various races of modern mankind; the *Sinanthropus* curve agrees closest with those designated as Amerindians, Greenlanders and Australian aborigines.

Manouvrier (1893) called attention to the fact, that in modern man the uppermost part of one nasal bone rather frequently encroached upon the other by sending out a small process beyond the midline. Such encroachment also occurs in *Sinanthropus* Skull XII (Fig. 81) where the left bone encroaches on the right side. The same peculiarity is found in Skull C of Krapina and in the Rhodesian Skull with the only difference that here the right bone encroaches on the left one.

2. Maxilla

Of the *Sinanthropus* maxilla only fragments are available; larger parts of the body are preserved only in Maxilla O I (No. V of the Catalogue of Facial Bones, see Table I; Figs. 142–147). Maxilla L II (No. III of the Catalogue of Table I; Figs. 148–152) merely consists of a part of the alveolar process and the lateral posterior wall of the sinus. Reference has already been made to the isolated frontal process No. I of the Catalogue of Table I (Figs. 135 and 136) in connection with the nasal bones (see the preceding paragraph). A small piece of the palate is represented by No. IV of the Catalogue of Table I (Figs. 157–159). In addition to these specimens there is a maxilla fragment of dubious character: No. VI of the Catalogue of Table I (Figs. 153–156). This maxilla was found among the skeletal remains from the "Upper Cave." But the morphological character of bone and teeth, the state of fossilization and the color suggest that the specimen belongs to *Sinanthropus*.

The *Sinanthropus* maxillae at hand are of different sizes. Maxilla No. V is larger than Maxilla No. III although both belong to adult individuals. This may indicate that the first belongs to a male and the second to a female individual, and certainly not that the former is of special size since the largeness of the temporal bone of Skull V and some upper teeth of our collection suggest considerably larger jaws than those recovered hitherto.

In his textbook R. Martin (1928) claims as a self-evident fact that the size of the body of the maxilla depends on the extension of the maxillary antrum. This is, of course, a complete reversal of the real conditions: the size of the upper jaw in the first place is correlated to that of the skull and then to that of the braincase, as was set forth in may paper on the brain and its rôle in the transformation of the human skull (1941b), while the size of the sinus is entirely of secondary order (see later). The sinus maxillaris is exposed in all the specimens (Figs. 135, 136, 145, 146, 149–151; sm); it occupies the entire body as is true in modern man and anthropoids but extends neither medially into the palate nor forward beyond the premolars as is the rule in the latter. On the other hand, the sinus descends considerably downwards into the alveolar process so that its floor is thrown into irregular elevations by the roots of the molars. In addition, since the palate is rather high the floor of the sinus in all cases is at a lower level than the floor of the nose. This feature also is in accordance with the average occurrence in modern man; Schaeffer (1910) found the sinus floor inferior to the nasal floor in 65 per cent. However, it seems that the *Sinanthropus* sinus extends further lateral than is usual in modern man; for the fragment of the os zygomaticum which consists of the central portion of the bone (Fig. 162) contains a very large zygomatic recess of the sinus. Keith (1902) has described a peculiar inflation of the nasal duct as characteristic of adult gorilla and chimpanzee, but *Sinanthropus* seems to be like modern man in this respect. The lateral wall of the maxillar sinus, it is true, is not preserved but the isolated frontal process of the maxilla (Figs. 135 B and 136 C) exhibits the sulcus lacrimalis (slm) from its beginning downwards to the crista conchalis (cco), that is, close to its opening into the meatus nasi inferior, with no indication of any special distension which must be developed if the conditions were the same as in gorilla or chimpanzee.

The facies anterior which is fairly well preserved in Maxillae No. V and VI (Figs. 142, 143, 144, 153) reveals some remarkable features which differ in characteristic manner from the corresponding ones in modern man. First of all, there is the prognathism. As a rule, anthropometric technique distinguishes three forms of prognathism: the total prognathism, almost identical with Camper's facial angle, i.e. the projection of the entire face; (2) the nasal prognathism, merely implying the projection of the nasal section of the maxilla, and (3) the alveolar prognathism which refers to the projection of the alveolar process only. Notwithstanding these different forms of prognathism, the contours of the profile have one feature in common, as far as the skull of modern man is concerned (cf. Fig. 168, C). If the skull is oriented in the Frankfort plane and looked at from the side, the crista nasalis which marks the rim of the apertura piriformis takes its course from the rhinion to the floor of the nose in a more or less pronounced curve. In orthognathous skulls the point where the curve joins the floor lies behind a perpendicular drawn from the rhinion to the floor; orthognathism is all the more pronounced the greater this distance. Even in those skulls which present a high degree of prognathism the curve, regardless of its special character, meets the floor behind the foot of the perpendicular or at least at the foot. In other words, the crista nasalis has a general tendency to run backwards or at least to follow a vertical line but it never runs forwards or, with reference to the entire apertura piriformis, it can be said that the aperture as a whole is erect while the roof portion is more or less overhanging (cf. Fig. 168, C). This is quite different in monkeys and apes; the crista nasalis runs continuously forwards in an almost straight line from the rhinion to the floor of the nose or, in other words, the apertura piriformis recedes as a whole, the roof portion taking part in this general orientation (cf. Fig. 168, A). The angles which indicate the degree of total and nasal prognathism merely give an approximate idea of the actual conditions.

In *Sinanthropus* the crista nasalis, perfectly intact in its inferior part, runs forwards continously and meets the floor of the nose in such an angle as to equal the conditions of chimpanzee (Figs. 142–144; 86 and 168, B). None of the skulls of the Neanderthal group with this facial part preserved show a similar form of prognathism; not one differs principally from those of modern man. This simian feature evident in *Sinanthropus*, however, only concerns the inferior portion of the apertura piriformis while the roof portion overhangs, thereby indicating human character.

The so-called alveolar prognathism is very pronounced in *Sinanthropus*. It is true that only the superior part of the exterior surface of the "clivus naso-alveolaris" remained intact, but since in Maxilla V the posterior walls of the sockets of the two incisors, the entire socket of the canine and, in addition, the lateral incisor itself are preserved the clivus naso-alveolaris could be restored with the utmost probability of accuracy; Figures 143–147 illustrate the extent of this restoration as indicated by outlines. As revealed in particular by Figures 144, 145; 86 and 168, B, the prognathism does not consist of a stretching out of the alveolar process with the profile contour forming a straight or slightly concave line as it is rather characteristic of highly prognathous maxillae of modern man (cf. Figs. 304 and 305 of my paper on the *Sinanthropus* dentition, 1937b, Pl. 32). On the contrary, the process bends downward with the profile contour forming a distinct convex line, thus recalling the conditions not infrequently found in anthropoids (cf. 1937b; Fig. 306, Pl. 32).

Of particular interest is the aspect of the passage from the nasal floor to the clivus naso-alveolaris. It is superfluous to discuss here all the manifold variations which are found in modern man; readers especially interested in this subject are referred to von Bonin's paper (1912). Only two of the variations merit mentioning. One, rather common among Europeans, consists of a sill-like elevation at the entrance of the nasal floor behind which the floor more or less inclines. The second one is rather frequently found in Australian natives and Melanesians and, therefore, considered a sign of primitiveness; in this case the clivus and the nasal floor are separated from one another not by an elevation but by the interposition of a depression which partitions from the clivus a furrow-like superior section, the so-called fossa or sulcus prenasalis. The latter type is very common in gorilla while the first one is specific of modern man. In *Sinanthropus* there is neither a sill nor a prenasal groove. The nasal floor is even and separated from the clivus merely by a simple "margo limitans" which is occasionally developed also in chimpanzee.

The same uncomplicated condition also characterizes the anterior nasal spine of *Sinanthropus;* it is true that just the midline of the spina region is broken off in the specimen in question. But if a well developed spine had existed, it would be indicated by the rising of the nasal floor, and that of the margo limitans and the surface of the clivus in the nearest vicinity of the spine; in other words, even if the spine itself were missing, it would have disclosed its existence at least by an elevation of the preserved base. Since nothing of this nature is indicated it is safe to say that *Sinanthropus* had no nasal spine or at best a very small one. This again is a simian character which sharply distinguishes anthropoids from man, although occasionally anthropoid skulls may be found with only a slight elevation and, on the other hand, human skulls with the spine reduced to a merely pointed elevation at the termination of the intermaxillar suture (No. 1 in Broca's instructions, 1875).

All of the skulls of the Neanderthal group have well developed nasal spines which in some cases (La Chapelle-aux-Saints, Gibraltar) even reach No. 3 of Broca's scale. The Rhodesian and the La Chapelle-aux-Saints skulls also possess distinct sills at the entrance to the nasal

floor; as to how conditions are in the remaining cases, I am not able to state since this information has been omitted from the description of the skulls by the respective authors.

The lateral region of the facies anterior of the maxilla between apertura piriformis and zygomatic process differs from that of modern man and the Neanderthal group by a rather significant peculiarity. In anthropoids there is a broad, prominent, rounded ridge which borders the aperture nearly in its entire height and runs downward to the canine in oblique direction. Lateral to this ridge there is a deep depression varying in size which begins at the foramen infraorbitale, and extends laterally to the root of the zygomatic process (cf. Figs. 168 and 169, A). The ridge is nothing more but the jugum alveolare of the canine which, corresponding to the length and strength of its root, is not only much broader and more bulging than any other alveolar juga but also reaches much higher upward; even in females the ridge is well developed and merely proportionally smaller than in males. In modern man the jugum alveolare of the canine is reduced to a relatively insignificant swelling strictly confined to the alveolar process itself and in no instance extending further upward than the nasal floor. The facies which borders the aperture is flat or even sunken and continues laterally into a more or less circumscribed depression, the so-called "fossa canina," against which the zygomatic process and the adjoining cheek bone jut out forward and sideward (cf. Figs. 168 and 169, C). The name "fossa canina" for this structure creates the wrong conception that it is in some connection with the canine. As a matter of fact, a "fossa" is present in anthropoids with huge canines and strongly developed juga as well as in modern man where this region is hollow. Even the strongest male gorilla with a widely bulging jugum regularly shows a more pronounced depression between the jugum and the base of the zygomatic process than is usually found in man (cf. Boule, 1911). Both topography and extension of the fossa indicate that it was caused merely by differences in the level between the lateral border of the aperture, the inferior border of the orbit and the malar region, regardless of the actual size of the maxilla.

Figure 164 demonstrates the topographical relation between the canine jugum, the fossa canina and the zygomatic process in horizontal section through the maxilla traced in about one half the height of the meatus nasi inferior. In gorilla (A) and chimpanzee (B) the jugum (jac) is broad and prominent, and the fossa canina (fcn) does not merely mark the bend of the contour while running from the jugum to the zygomatic process (pz) but represents in itself a light depression (cf. also Fig. 169, A). In modern man (E–G) the jugum has disappeared completely but the fossa remains in its original place. In extreme cases, as exemplified by an Amerindian skull (G), the maxillar body between the meatus nasi inferior and the facies anterior is reduced to a thin wall and the fossa appears as a wide and deep impression occupying almost the entire anterior facies (cf. also Fig. 169, C). The conditions of *Sinanthropus* (C) are distinctly intermediate between anthropoids and modern man, the jugum being well developed and the wall fairly thick (cf. also Figs. 87 and 169, B). *Sinanthropus* differs from the anthropoids only as far as the jugum is less projecting, a divergency caused not as much by an underdevelopment of the jugum itself as by the less pronounced prognathism of the upper jaw. It is significant that none of the Neanderthal skulls equals *Sinanthropus*. Even in the Rhodesian skull (D), equipped with the largest and heaviest maxilla of all the skulls of this group, the jugum is missing and the configuration of the facies anterior not essentially different from modern man with heavy jaws (cf. D and E).

It is often reported that the fossa canina is absent or nearly absent in Neanderthal skulls. Such statement is true to some extent only, and even if so, the absence is not necessarily a sign

of primitiveness as surmised by certain authors, for all anthropoids have a well defined fossa canina.   When speaking of the absence of the fossa authors mean that the facies anterior of the maxilla is completely plane and not sunken as is the rule in man.   Even in the Rhodesian skull there is a slight depression below the foramen infraorbitale, as indicated in Figure 164 (D). In *Sinanthropus* Maxilla V, however, the fossa has a special appearance inasmuch as it shows a greater resemblance to a furrow than to a fossa.   (Figs. 143, 144, 164; fcn).   It begins immediately below the foramen infraorbitale—the margins of the foramen itself are not preserved— and runs downward and slightly forward towards the interstice between the first and second premolars.   At its origin the "fossa" looks like a deep notch (fcn) between the large swelling of the canine jugum (jag) and the salient zygomatic process (pf).   In Maxilla III (Fig. 153) conditions seem to be the same, although the upper portion of the furrow is broken off.   The development of such a "sulcus maxillaris" which replaces the "fossa canina" of modern man is a novelty.   Yet I do not consider its formation in *Sinanthropus* an accidental one, because the form which the fossa canina can assume in chimpanzee resembles the sulcus of *Sinanthropus* rather closely.   It may be superfluous to stress the fact that the sulcus is certainly not caused by the nerves and vessels which the foramen infraorbitale admits to the malar region though the sulcus takes its origin there, but must be considered a kind of fold between the two prominences, the canine jugum, on the one side, and the zygomatic process, on the other.

Burkitt and Hunter (1922) described a similar structure as "infraorbital fossa" in the very primitive skull of a female Australian; they explain its formation as being developed between the two bony buttresses responding to the thrust from the canine and incisors, on the one side, and the molar teeth, on the other.   According to Fenner (1939) it is impossible to distinguish in Australian skulls between an "infraorbital fossa" proper and the canine fossa: "the two fossae may be present and separated by a small bony prominence, and either infraorbital or canine fossa may be present alone."   He found a large and deep infraorbital fossa in 28 per cent of males and 27 per cent of females.   As shown above, the essential feature is not the infraorbital "fossa" but the infraorbital "sulcus."   Its formation is dependent on the development of such a large canine jugum as is never found in man; the existence of a real fossa is always an indication that the process of reduction has set in already.

The zygomatic process in modern man represents a trihedron with a superior, anterior and a posterior side.   The corner where the latter two sides meet very often is a sharp edge which obliterates in its course downwards; it can be called "malar pillar" because of its continuation into the malar bone and the malar tuberosity.   When viewed from in front the edge usually forms a low and wide arc which, however, varies considerably in height and degree of curvature. In many cases the pillar is not edged but instead there is a broad, rounded lateral surface.

In the *Sinanthropus* Maxilla V in which almost the entire process is preserved the base is very broad (Figs. 144, 146, 147, pz), and the malar pillar not edged but perfectly rounded.   But a more characteristic feature is the lowness of the arc, which is due to the narrowness of its curvature and the pronounced downward bend of its malar extremity (Fig. 143, ima).   That this peculiarity cannot be dismissed merely as an individual variation but must be regarded as peculiar to *Sinanthropus* follows from Maxilla III in which the narrowness of the curvature and the downward projection of the malar extremity is still more accentuated than in Maxilla V (Fig. 149; ima).   I call the notch thus formed "incisura malaris."

The significance of this peculiarity becomes all the more apparent when taking into consideration that in all known Neanderthal skulls the malar pillar runs highly upward in an almost

straight or only slightly curved line; a low zygomatic process and a downward bend of the malar extremity of the pillar has so far never been observed in fossil hominids. Some students of fossil man arrived, therefore, at the conclusion that a high maxilla and a straight pillar line are primitive characteristics. That this is not so, however, is proven by the conditions of *Sinanthropus*. Yet it is interesting to note that a high maxilla and a straight pillar line are only found in gorilla and chimpanzee while in orang-utang the same conditions occur as in *Sinanthropus;* the pillar line of orang-utang not seldom forms a very narrow arc, having its malar extremity sharply curved downward. I shall return to this question later when discussing the malar tuberosity.

Fenner (1939) referring to Krogman (1932) records the very frequent occurrence of a concavity of the inferior border of the maxilla "so that the facial aspect of the malo-maxillary suture was situated on a downward projection lateral to the concavity." When the curve of the lower border forms an arc of less than one quarter of a circle Fenner recorded the zygomatic process as "normal" but as "concave" when the suture was situated on a downward projection. According to Fenner's figures there is practically no Australian skull that does not show a curved inferior border while in 47 per cent of males the curve is "concave" in Fenner's sense or, in other words, there is an "incisura malaris." The conditions found in *Sinanthropus* are, therefore, rather common among Australian skulls while the straight contour line encountered in all of the Neanderthal skulls and considered primitive by authors seems to be extremely rare in this race.

The maxillary tuber of *Sinanthropus* is not preserved in any of the specimens, except for the part adjacent to the posterior facies of the zygomatic process which, however, fails to reveal any particular difference from that of recent man.

Very little of the medial side of the maxilla is preserved. But in the fragment of the frontal process (No. 1, Figs. 135 B and 136 C) the crista ethmoidalis (cem) and crista conchalis (cco) are very distinct while in the maxilla fragment No. VI (Fig. 155) only the crista conchalis (cco) is preserved. With regard to the development and course of these crests there is no distinctive difference between *Sinanthropus* and modern man; the only thing worth mentioning is the fact that the frontal process does not show any indication of a so-called "aggar nasi," a swelling in front of the crista ethmoidalis which authors consider a relic of the nasoturbinale of quadrupeds. As to the sulcus lacrimalis, see above.

Form and size of the alveolar process and the dental arc will be discussed in the paragraph dealing with the restored skull since but small parts are preserved. Notwithstanding the scarcity of the material, it can be stated that buccal maxillar exostoses were apparently a common occurrence in *Sinanthropus*. In Maxilla III the entire intact border of the alveolar process from the first premolar to the third molar is set with a continuous line of typical bony excrescences (Figs. 149, 150, 152; ex) which are highest in the region of the second molar. In Maxilla V the buccal border of the alveolar process is only preserved above the second premolar (Figs. 143, 144; ex), but precisely there a large exostosis has developed. Strangely enough the same is true of Maxilla VI. In this case, too, the border in question is broken off, except for a short portion above the interstice between the first and second premolars (Fig. 153 ex), and here too a small exostosis is present. Lingual exostoses are absent in all cases.

From these facts it can be deduced that in *Sinanthropus* buccal maxillar exostoses are not only a rather regular occurrence but that they seem to occupy even a larger area than in modern man. Hrdlička (1940), the latest author who dealt with this particularity in modern man,

states that maxillary overgrowths "are peculiar to the molar regions . . ., though they extend forward as far as P₂—very exceptionally even to the canine—and to beyond M₂ backward." Still more interesting than its occurrence in *Sinanthropus* is the fact that they are seemingly even more frequent than in modern man.   Of course, it would be hazardous to express their occurrence in percentage since not more than three specimens are available.   Nevertheless, the fact that these exostoses are present in all of the three specimens (100 per cent) proves that, at any rate, they must have been more frequent in *Sinanthropus* than in modern man; for Hrdlička found buccal exostoses only in 2.5 per cent of Siberian crania and in 4.5 per cent of crania of Koniags and Aleuts.   According to the same author Schreiner encountered such exostoses on Lapp's skulls in only 3.9 per cent and Murakame on Japanese male skulls in 5.2 per cent but nil in females.   These data refer exclusively to Mongolian types of modern mankind while no data seem to be available so far of other racial groups.   Hrdlička found the maxillar exostosis of modern man more frequent in males than in females.   The *Sinanthropus* Maxilla V is probably that of a male and Maxilla III that of a female, Maxilla VI that of a second male.

As I have demonstrated in the publication on the *Sinanthropus* mandible (1936b), a mandibular exostosis—torus mandibularis—is well developed in two of the four adult mandibles in which the predisposed parts are preserved.   Since then two additional adult mandibles have been recovered, one with and the other without a torus.   Of six *Sinanthropus* mandibles, therefore, three or 50 per cent have a well developed mandibular torus.   Since a similar high ratio and even higher ones are reported of certain Mongolian racial groups and since other features characteristic of *Sinanthropus* point to the same direction (see later) I concluded that *Sinanthropus* is more closely related to the Mongol race of today than to other races.   In the publication mentioned before Hrdlička (1940) deals also with the mandibular torus and its occurrence in modern man.   The author denies its racial character because it may be found among all races of recent mankind.   But this is, of course, not the point.   All features, with very few exceptions, used for discriminating races can be found in many races; the question is to what percentage or degree of development do they occur in given groups.   Pigmentation of epidermis and hair is generally used as a racial characteristic but pigmentation as such is found among all races, including the whites; the essential factor is just the amount of the pigment.

With reference to the mandibular torus Hrdlička's own figures on the occurrence of the torus in certain races prove him to be wrong.   I have taken Table XVII over from his "Original new data" (p. 8 of Hrdlička's publication); the only alteration I have made concerns the sequence of the groups, their contraction and the insertion of *Sinanthropus* at the proper place. In any case, it follows from these figures that the torus mandibularis is much more frequent in Mongols than in all of the other races and again that some groups within the Mongols exceed others to a remarkable degree.   *Sinanthropus* with a very high percentage takes his place between the Alaskan Eskimos and the Koniags and Aleuts.

To return to the maxillar exostosis, there is no doubt that its structural character differs from that of the mandibular torus; the maxillar exostosis consists of small granulations which tend to flow together but never form such a homogeneous smooth projection as is typical of the mandibular exostoses.

As to the occurrence of buccal maxillar exostoses in other fossil hominids nothing has been reported so far.   *Pithecanthropus* Skull IV shows a small isolated outgrowth on the alveolar border of the right side above the first molar.   In the Rhodesian Skull there are several large excrescences within the molar region of the right side and a smaller but much more prominent

TABLE XVII

Occurrence of Torus Mandibularis in Certain Races, According to Hrdlička's (1940) Observations

Group	Number of Specimens	Percentage
Melanesians	29	0.0
Old Egyptians	166	2.4
Old Peruvians	465	3.4
Polynesians	74	4.1
African and American Negro	53	11.3
North American Indians	2000	13.5
Australians	12	16.7
Diverse Asiatic Mongols	235	26.4
Alaskan Eskimos	1205	40.0
Sinanthropus	6	(50.0)
Koniags and Aleuts	611	61.8
Lapps	6	(83.3)

one on the left side; the same skull also has lingual exostoses on either side. But neither the buccal nor the lingual ones are mentioned in Pycraft's description of the skull (1928). Whether these outgrowths can be considered as "normal" maxillary exostoses, however, is doubtful because decay of the teeth is far advanced, and there is much evidence of alveolar pyorrhea, particularly on the left side.

The palate process in connection with the maxilla is partly preserved in Maxilla III (Figs. 151 and 152), V (Figs. 145 and 147) and VI (Figs. 154–156); the greater part of the right side is represented by an isolated fragment which may belong to Skull X (Figs. 157, 158). Yet the material on hand is so deficient that it gives only a vague idea as to size and form of the *Sinanthropus* palate. Nevertheless, it does supply some important indications about the appearance of certain features which are of interest from a comparative viewpoint.

No sutures are preserved. But the breakages of the palate in Maxilla V (Fig. 147) and the isolated palate fragment (Figs. 157 and 158) follow the midline so accurately as to suggest the persistence of the sutura palatina mediana in both cases. Maxilla V shows the anterior portion of the palate, at least that of the left side, but there is no trace of a sutura incisiva, although this suture may persist in adult skulls of modern man of all races occasionally up to 50 and more per cent.

The canalis incisivus is preserved in Maxilla V (Figs. 145 and 147, cic) in its entire length. Its position differs from that of modern man in so far as the palatal orifice of the canal in *Sinanthropus* lies at a greater distance from the orale than is true in the former. In modern man the anterior wall of the canal begins immediately behind the orale, and the canal ascends almost vertically. Even in cases with pronounced alveolar prognathism there is no essential difference as to the position of the orifice and the direction of the canal. In *Sinanthropus* Maxilla V the alveolar border of the midline is broken off but, since it is preserved behind the lateral incisor, the position of the orale can be determined with great accuracy. The palatal extremity of the incisive canal is entirely preserved; the groove and particularly the ridge that bounds it laterally obliterate more than 5 mm. behind the supposed orale. As the posterior wall which forms the posterior rim of the orifice is not preserved, it is difficult to determine accurately how far off from the orale the rim may have been. I estimate the distance between the two points at 17 mm. The canal runs for- and downwards in a fairly inclined line which forms an angle of about 40° with the alveolar plane (Fig. 145). The distance of the nasal orifice of the canal from the orale amounts to at least 24 mm. These distances and such an angle of inclination far exceed

the average conditions of modern man. However, since no concrete figures are available it is sufficient to stress the principal differences. In any case, *Sinanthropus* recalls in this regard the conditions characteristic of the anthropoids. For in all three types the palatal orifice of the incisive canal lies far behind the orale and the canal runs forwards and downwards in a fairly oblique line with an angle of inclination that does not differ essentially from that observed in *Sinanthropus*. Despite the strong alveolar prognathism of chimpanzee and gorilla the nasal orifice of the canal lies very close to the entrance of the nose. Even in the big male gorilla does this distance vary from about 10 mm. to 15 mm. In modern man this distance is about 10 mm. and the same is true of *Sinanthropus*. The alveolar prognathism, therefore, affects mainly that part of the jaw which is situated anterior to the canalis incisivus or, in other words, the position of the premaxilla. In this point *Sinanthropus* resembles the anthropoids much more than he does modern man.

The more surprising is the fact that in the appearance of the palatal surface *Sinanthropus* is strikingly human-like. The surface is rugged in all the parts preserved (Figs. 147, 157, 158). This ruggedness is caused by depressed areoles separated from one another by low irregular crests or fine ridges which are arranged in more or less longitudinal direction. In Maxilla V (Figs. 145 and 147) the opening of the incisive canal is bounded by a pronounced ridge which obliterates towards the alveolar border—crista mediana (cme). Such a ridge accompanying the median palatal suture on either side is very common in modern man. An additional feature, likewise not infrequent in the latter, is the existence of a sulcus palatinus medialis (Figs. 157 and 158, spl) caused by the vasa palatina. In anthropoids the palate exhibits quite a different aspect. Except for the premaxillar section, the surface is almost completely smooth in all three anthropoids. *Sinanthropus*, therefore, shows a pronouncedly human character in this regard. This is all the more surprising because the palate of *Pithecanthropus* Skull IV (Fig. 248) displays a smooth palate like that of gorilla with no indications whatever of ridges or areoles. On the other hand, in all of the Neanderthal skulls the general pattern of the palate is a human one, the ridges being particularly well developed in the Rhodesian Skull. No reports are available on the location of the palatal orifice and course of the incisive canal in the Neanderthalians; as far as casts permit judgment there is no essential difference between the Neanderthalians and modern man.

Whether or not *Sinanthropus* had a torus palatinus is impossible to decide since the posterior parts of the palate comprising the preferential seats of this structure are missing.

3. Os zygomaticum

The os zygomaticum of *Sinanthropus* is only known by three fragments. One is represented by Facial Bone No. II which probably belongs to the male Skull X (Figs. 160–163). This fragment comprises the major portion of a left bone extending from the infraorbital margin to the malar tuberosity while the temporal as well as the frontosphenoidal processes are broken off. On the other hand, a part of the zygomatic process of the maxilla adheres to the fragment; since, however, the zygomaticotemporal suture is completely obliterated the original boundary between the two facial elements is no longer discernible. A depression within the center of the fragment and a smaller pit on its lateral side perhaps indicates some remainder of a suture.

A second fragment of the zygomatic bone is represented by the greater part of the left frontosphenoidal process of Skull XII still in contact with the zygomatic process of the frontal bone (Figs. 79–81, 84, 92). The process includes the anterior portion of the lamina orbitalis

with the facies orbitalis and temporalis. The third fragment of a zygomatic bone is rather small, comprising a part of the frontosphenoidal process and probably belonging to Skull X; on account of its smallness I omitted entering it in the Catalogue of Table I but I wish to mention it here.

Because of the fragmentary conditions of the entire material it is impossible to describe the bone as a whole; nevertheless there are several interesting details worth recording on account of their bearing on the comparative anatomy of man.

The main fragment (II; Figs. 160–163) is very high, the distance between the infraorbital and the masseteric margins measuring 31.5 mm. (Rhodesian Skull 27.5 mm.). When the height of the frontosphenoidal process with about 35 mm. is added, the entire height of the bone would total circa 65 mm. Kleiweg de Zwaan (1933) gives the following figures of the average height on the basis of his own measurements and those derived from other authors: Japanese 44.7 mm., Bohemians 44.5 mm., Lapps 44.5 mm., Papuas 46.5 mm. The maximum values of the Papuas amount to 59 mm. and those of the Lapps to 57.6 mm. Woo (1937) measured the vertical arc of the zygomatic bone extending from Martin's "frontomalare temporale" (fmt) to the "zygomaxillare" (zm). Woo's list includes all of the main races of modern man; the averages vary from 46.2 mm. (Kanaka) to 52.6 mm. (Chinese). The highest maximum value of all the races is found among Chinese and amounts to 59.8 mm., but it must be borne in mind that in any case the arc exceeds the chord in length the measurements of which are recorded by Kleiweg de Zwaan. Therefore, it does not seem to be too far removed from truth if it is assumed that the maximum value of the height even in those races of modern man (Mongols) which have large zygomatic bones does not exceed 60 mm. *Sinanthropus* with circa 65 mm., therefore, certainly possesses a zygomatic bone the height of which falls considerably beyond the range of modern man. This difference is still more apparent as the corresponding measurement of the zygomatic bone of the Rhodesian Skull is only 54 mm. although this skull is remarkable on account of its height maxilla; none of the other Neanderthal Skulls has a higher zygomatic bone than the Rhodesian Skull. Unfortunately, it is not possible to determine the breadth of the zygomatic bone of *Sinanthropus* since the orbital extremity of the zygomaticomaxillar suture is not preserved and the entire temporal process is wanting.

As to the facies malaris, it is noteworthy that the entire anterior inferior area shows a distinct prominence (Fig. 161, tm) which projects also beyond the lower margin of the bone. Viewed from below (Fig. 163, tm) this malar tuber appears as a knob-like thickening of the whole region. The surface of the projection is generally smooth, but crossing it from front to back there is a slightly rough band which continues in an elevated line directed upward on the reverse side, the facies temporalis. This structure probably represents the remainder of the obliterated zygomaticomaxillar suture. Just above the upper extremity of the prominence of the facies malaris there is a single hole (Fig. 161, fzf), foramen zygomaticofaciale, which does not differ from that in modern man. The knob-like structure of the malar tuber and the thickness and smoothness of the bone may also occur in modern man, but certainly cannot be considered a common feature, although I was unable to find any references concerning the special appearance of the tuber.

In discussing the zygomatic process of the maxilla I already called attention to the fact that there is in *Sinanthropus* a deep notch which separates the masseteric margin and the malar tuber from the ascending root of the process—incisura malaris (cf. Figs. 143 and 149; im). The downward projection of the malar tuber itself is a further demonstration of the general

character of this feature. The notch is in reality much deeper than it appears in Figure 161, for as shown in Figure 163 the lower surface of the zygomatic process of the maxilla is broken off so that the contour appears level. In all cases of fossil hominids in which the part in question is preserved the malar tuber projects forward but not downward nor is there any indication of an incisura malaris.

The margo infraorbitalis is preserved only to a small extent, and just in that section where the margo turns from the horizontal to the upward direction. Despite the smallness of the fragment certain peculiarities can be defined (Figs. 161 and 162): (1) there is no sharply edged margin but a rounded one, (2) the facies orbitalis does not slope to a deep depression beyond the margin but keeps to the same even level, (3) there is a relatively large foramen zygomatico-orbitale inferius (fzo) which differs from that of modern man in so far as its entrance is not placed on the ascending lateral wall of the orbit but on the floor.

An even orbital floor and a rounded inferior lateral angle also occurs in modern man; Adachi (1904) states in this regard: "The edge of the entrance is sometimes, in particular at the inferior lateral angle, rounded so much that the malar facies of the os zygomaticum continues into the orbital one without any boundary. However, I found very well rounded edges rarer in European skulls than in those of Japanese." I failed to find any data recording the frequency of this feature in different races but, as much as I was able to see, an even floor and a rounded inferior lateral angle, as they occur in *Sinanthropus*, are rather common features in Mongolian skulls. In Australian skulls rounded borders seem to be very frequent, too; according to Fenner (1939) they occur in 45 per cent of males and 12 per cent of females. Fenner's figures, however, include the upper border and, moreover, refer to the conditions of the entire margin; they are, therefore, of little value when dealing merely with the inferior lateral angle. It seems that all of the Neanderthal skulls, so far as the region in question is preserved, show the same peculiarity as *Sinanthropus*.

Size, form and position of the foramen zygomatico-orbitale inferius as described for Fragment No. II (Figs. 161 and 162; fzo) are exactly the same as in Skull XII (Fig. 80; fzo). In this case the anterior extremity of the inferior orbital fissure is also preserved, indicating that the foramen lies in direct line with the fissure and, therefore, more medially than in modern man. The fact that in the two *Sinanthropus* specimens in which this region is preserved the conditions are identical proves that we are dealing with a general character and not with merely an accidental occurrence. This is all the more important as the Rhodesian Skull is the only one of the Neanderthal Skulls that resembles *Sinanthropus* completely with regard to the localization of the foramen zygomatico-orbitale inferius.

Fenner (1939) describes the malar tuberosity in Australian skulls as taking the form of a prominent ridge on the malar surface running parallel with the inferior border of the bone. What Fenner apparently has in mind is a ridge-like elevation of the superior part of the malar surface immediately adjacent to the infraorbital margin. Such a feature is absent in *Sinanthropus;* the central depression of the surface I mentioned above makes the superior part slightly prominent but it certainly does not deserve to be called a ridge. Besides, a ridge in this place is not at all identical with the malar tuberosity as suggested by Fenner, for this formation is confined under all circumstances to the inferior part of the surface and the inferior border (cf. Figs. 161 and 163; tm).

In European races of modern man the facies malaris is directed more sidewards than forwards. Apart from this the whole zygomatic bone is oriented in such direction that an outline

of the malar facies which runs from the infraorbital margin to the lower border take a more or less backward course. This is quite different in skulls of the Mongolian racial types; in those cases the malar surface faces forwards rather than laterally, and the outline takes a more vertical direction. Both peculiarities are among other factors mainly responsible for what has been called broad and prominent cheeks and a "flat face." The facies malaris of the *Sinanthropus* zygomatic bone very definitely shows the Mongolian type in both these characters (cf. Figs. 86 and 87).

Several methods of measurement have been suggested for the determination of the type to which a given skull should be attributed; all of these methods are complicated and none of them applicable to isolated fragments like those of *Sinanthropus*. But there is a very simple procedure which permits one to judge with some accuracy whether and to what degree the facies malaris faces forwards or sidewards. When Mongolian skulls with broad cheek bones and flat face are viewed from the base, the anterior outline of the maxilla almost up to the zygomatico-maxillar suture is oriented in a frontal plane while in non-Mongolian skulls the outline tends backwards nearly from its start above the alveolar process. In addition, in Mongolian types the part of the zygomatic bone, which joins the maxilla, first keeps to a frontal direction and then bends backwards in a moderate curve whereas in non-Mongolian types the entire zygomatic arch faces laterally with the turning point falling at the zygomatic process of the maxilla. In extreme cases the turning is very abrupt and the curve narrow. Figure 165 illustrates these conditions: A, D and E represent pronounced Mongolian types: A a Mongol skull from Mongolia; D an Alaska Eskimo of Point Hope; D an Eskimo of Greenland. G and H are typical non-Mongolian types: G an European of unknown provenance; H a Melanesian of New Caledonia. All are male individuals. In non-Mongolian types (G, H) the anterior wall of the temporal fossa turns backwards almost in an angle whereas in Mongolian types (A, D, E) the turn is a wide-spanned curve. *Sinanthropus* (B) undoubtedly reveals the Mongolian type although it is impossible to determine the exact orientation of the fragment in relation to the frontal plane. However, since the anterior wall of the temporal fossa is preserved the error can in no case be so great as to affect substantially the result.

It is noteworthy that none of the Neanderthal skulls shows a similarly pronounced frontal orientation; the malar surface of all of them faces laterally. Even in the Rhodesian Skull in which one may expect a frontal orientation considering the seemingly great breadth of the face the entire lower margin of the zygomatic arch already retreats from the zygomatico-maxillar suture (Fig. 165 F), and the zygomatic process itself is directed more backwards than sidewards. The anthropoids differ from one another: in gorilla (C) the frontal orientation is most pronounced, then follows orang-utang (K) while in chimpanzee (I) the entire arch has a sideward direction.

In describing the maxilla attention had been drawn to the great extension of the maxillary sinus. Figure 162 shows that it reaches laterally up to a sagittal plane laid through the foramen zygomaticofaciale. The same figure reveals that the wall separating the sinus from the temporal fossa is much thicker than it is in modern man under similar conditions.

The processus frontosphenoidalis of the zygomatic bone is almost completely preserved in Skull XII (Figs. 79–81, 84, 92). The lamina orbitalis reaches the sutura sphenozygomatica. The process is broken off just medial to the extremity of the lower orbital fissure (Figs. 84, 92; foi) so that the superior lateral recess of the maxillar sinus is exposed (sma). The malar facies of the process, however, together with the infraorbital border is missing in Skull XII; but since

this region is preserved in Fragment No. II (Figs. 161 and 162) it is possible to obtain a good idea of the characteristics of the entire frontosphenoidal process.

One of the most striking features is the frontal orientation of the process when viewing Skull II from in front (Fig. 81). This peculiarity evidently is in accordance with the frontal orientation of the malar facies described above. In order to determine the degree of this orientation and compare it with the condition in modern man, I worked out a relatively simple method that yielded quite satisfactory results. The skull is fixed in norma basalis and then the entire outline of the process, beginning on the facies orbitalis and ending on the medial wall of the fossa temporalis, is traced in horizontal plane at the level of the greatest breadth of the process. The boundaries of the facies malaris are sharply marked by the edges where the facies malaris turns into the facies orbitalis, on the one side, and into the facies temporalis, on the other. When the straight line connecting the two edges with one another is continued on the diagram up to the mid-sagittal line, the angle it forms with the latter indicates the degree of inclination of the malar facies to a frontal or a parasagittal plane. In other words, when the facies malaris of the frontosphenoidal process shows a more frontal orientation the angle approaches a right one; when the facies, however, is directed more laterally the angle becomes more acute. These conditions are illustrated in Figure 166. In order to economize space the mid-sagittal line is shifted 25 mm. laterally but the original position of the diverse processes depicted in this figure were kept so that the real distances from the midline can be read off in each case by the addition of 25 mm.

As may be seen from Figure 166, there is a great variation in the orientation of the facies malaris in man and anthropoids. As far as modern man is concerned, the extremes are represented by G and H, on the one hand, and C and D, on the other. G and H are European and Melanesian, respectively, the same skulls used in Figure 165 to demonstrate the orientation of the maxilla and the zygomatic arch; C and D are Eskimo skulls, again the same as in Figure 165. In the European as well as in the Melanesian the angle of inclination of the facies malaris is 30° whereas it totals 57° and 55° in the Alaska and Greenland Eskimos. The figures show that the frontosphenoid process has the same orientation as the body of the zygomatic bone: in Mongolian types the malar facies faces forwards while in non-Mongolian types it is directed sidewards. *Sinanthropus* (F) follows the Mongolian type with an angle of inclination of 50° while the Rhodesian Skull with an angle of only 29° goes the opposite direction. So far as I was able to determine, all of the Neanderthal Skulls exhibit a non-Mongolian type. Regarding the anthropoids the orientation of the process is markedly frontal in all types: chimpanzee (A) leads with an angle of 84°, gorilla (B) follows with 70°, and orang-utang (E) with 52° comes very close to *Sinanthropus*.

The transverse section through the *Sinanthropus* frontosphenoid process as illustrated in Figure 166, F, again reveals the massiveness of the bones which has been found to be a characteristic feature of this hominid. This massiveness of the process is equalled only by the Rhodesian Skull (I) which, however, as a whole is much heavier and larger than any of the *Sinanthropus* skulls, and by the orang-utang (E) while all of the depicted processes not only those of modern man but also of chimpanzee and gorilla are much thinner and more slender.

The orbital and temporal borders which bound the malar facies of the process have fairly sharp edges; *Sinanthropus* does not differ from modern man in this respect. The temporal border, however, shows a peculiarity which, though it also occurs in modern man, deserves mentioning on account of the mistaken interpretation of that formation. Below the zygomatico-

frontal suture the temporal edge projects considerably, widening the breadth of the malar surface of the process to almost double (Figs. 79 and 167; pmg). The occurrence of such projection in modern man is a well known fact and recorded under the name of "processus marginalis." That this feature does not represent an accidental variation in *Sinanthropus* but rather a common occurrence is proven by the fact that it is also present in an isolated fragment probably belonging to Skull X which, however, is too small to warrant an illustration.

According to the literature the marginal process is found as an occasional structure in all races of modern mankind. But there cannot be any doubt that it is more frequent and more pronounced in Mongolian races than in others. Stieda (1870) refuted, it is true, the statement made by Schultz (1852) who first claimed its restriction to Mongolian elements, yet Stieda's own experience showed the process to be developed mostly in Finns, Estonians and Chukchis. Fenner (1939), in recording the frequency of the process in Australian skulls, found it moderately developed in 42 per cent of males and 39 per cent of females and greatly developed in 28 per cent and 10 per cent, respectively. Unfortunately, no further statistics on its occurrence in skulls of Mongolian races are available. The presence of the process in *Sinanthropus* in any case is all the more remarkable since it is completely missing in Neanderthal skulls.

As to the significance of the marginal process the only reference I was able to find is a statement made by Eisler (1912) who describes the origin of the temporal muscle as follows: "The succession of muscle and fascia bundles in the superficial layers of the anterior portion of the temporalis is usually less numerous than in other portions of the muscle, yet there is an additional muscular portion that arose from a strong tract attached to the marginal process of the zygomatic bone and branching out backward and upward." Eisler brings the process in direct connection with the temporal muscle but almost every skull shows some, more or less pronounced rough lines around the temporal edge in the region where the process usually arises, regardless of whether it is developed or not.

The temporal muscle can thus hardly be made responsible for the formation of the process. What causes the appearance of a projection of the temporal border below the zygomaticofrontal suture is not an actual projection of the edge but, to the contrary, a contraction of the entire frame of the orbit above and below the zygomaticofrontal suture which mainly affects the temporal side of the edge. Speaking of a frontomalar notch or "incisura zygomaticofrontalis" (Fig. 167; izf) would, therefore, apply to the real conditions much more than the term now in use. In many cases this notch is correlated with a shallow or deep notch below where the frontosphenoidal process meets the temporal process of the zygomatic bone—"incisura zygomaticotemporalis" (Fig. 167; izt). If the latter indentation is also developed, the "marginal process" (Fig. 167, C; pmg) seems to jut out still more.

In Figure 167 the lateral frame of the orbit of some typical cases is depicted directly viewed from the side of the greatest extension. C shows the conditions in a recent Mongolian skull the orbital frame of which is more than twice as broad in the region of the so-called marginal process than it is in the suture region above. There also is a distinct notch below the process (izt). D illustrates the condition of *Sinanthropus* Skull XII which corresponds to that of C. In E the frame of a European skull is figured, which continues to be narrow in the entire length without any indication of a process or notch above or below. B, the Rhodesian Skull, is the counterpart of E, with the only difference that the entire frame is double the breadth of the latter. In anthropoids no marginal process exists but the orbital frame is broadest just above the suture and tends to narrow below it, as exemplified in gorilla (Fig. 167, A).

The reason for dwelling upon these details is because I consider the narrowing of the lateral orbital frame, whether as a whole or confined to its upper and lower ends, an additional example of the general tendency in human evolution to reduce size and strength of the facial skeleton. It may well be that an exceptionally strong development of some particular muscular bundles of the temporalis prevents a special area of the temporal border of the zygomaticofrontal process to participate in this reduction, so creating the misconception of a progressive formation which actually does not exist.

Neither the orbital nor the temporal facies of the zygomaticofrontal process reveals any difference from the conditions of modern man. In Skull XII there is a small foramen zygomati-co-orbitale superius, while the foramen zygomaticotemporale is not recognizable. The facies temporalis exhibits at the level of the marginal process an indistinct vertical line which is much more developed in the above mentioned fragment of the process belonging to Skull X. This line, not rarely found also in modern man, apparently serves as an attachment for muscular bundles of the temporalis. It is pronounced in the Rhodesian skull and can reach extraordinary dimensions in chimpanzee.

B. Reconstruction of Skull and Physiognomy

The braincase, as described, is preserved in several specimens almost in its entirety, but in all cases the central portion of the base is lacking. Parts of the facial skeleton at hand are not so complete, and, with the exception of the mandible, they are represented merely by one or two pieces for each special feature. Nevertheless, all of the characteristic structures of the face are substantiated by actual finds so that their appearance can definitely be established. The only parts missing comprise the free portion of the zygomatic arch and a small area of the maxilla extending from the infraorbital foramen upwards to the infraorbital margin.

Such being the case, a reconstruction of the skull was relatively simple and, in any case, not so much of a hazardous undertaking as it would have been if only the calvaria were available to serve as base. We already know and it will be demonstrated again in one of the following chapters that a certain correlation exists between size and form of braincase and face. But this general knowledge fails to offer any indication regarding the special configuration of the various features of the face, especially when an entirely unknown hominid form is the subject of those attempts. The truth of this statement is evident when comparing Weinert's (1936/37) reconstruction of the *Sinanthropus* skull with the one submitted herein. Of course, there is some correct guessing in Weinert's work but only as far as the aforementioned generalities are concerned. In almost all the other details, however, there are essential differences from those supposed by that author; one important miscalculation in the reconstruction he made, for instance, involves the maxillar portion of the face which extends much further downward than Weinert ever presumed.

Our task was to bring the braincase and the various fragments of the facial skeleton together to fit into one another in correct proportions. Of the three most complete calvariae available (Skulls III, XI and XII) I chose Skull XI. This skull certainly belongs to a full grown individual and, in addition, some of the facial fragments belong to this calvaria, even though the connecting parts are missing. The only disadvantage, if it should be considered as such, is that Skull XI probably represents a female and, therefore, would not display all of the peculiarities of the *Sinanthropus* type to such an exaggerated extent as would be true of an adult male individual. As certain fragments of the face were of larger dimensions because they belong to

the male (but more defective) Skull X and other ones to the male Skull XII, they had to be specially adjusted to the female skull. Since two maxillae certainly belonging to *Sinanthropus* were available the upper jaw No. III, probably belonging to Skull XI, was selected and completed from parts preserved in the second case (No. V). This piece has five teeth in place, all fairly worn. The conditions of the cranial sutures of Skull XI prove the individual to have been of an advanced age; the same status is indicated by the degree of attrition of the upper teeth. This being the case, the reconstruction of the dentition had to follow the same line. This was all the more justified since an entirely unworn set of teeth had already been described in my publication on the *Sinanthropus* dentition (1937b, Plate 25, Fig. 239b). As to the lower jaw, Mandible H I (cf. 1936b) comes closest to the maxilla in size. In addition, this mandible apparently belongs to an old female individual as is indicated by the size of the jaw and size and attrition of the only preserved tooth (last molar). As was to be expected, a discrepancy existed between the breadth of the skull base, the "lateral interglenoidal breadth" and the bicondylar breadth of the jaw. The breadth of the latter (102 mm.) is somewhat inferior to that of the former (126 mm.). The condyles could be adjusted by merely turning the condyloid process slightly outward (adapted bicondylar breadth: 124 mm.). As was already shown in my publication on the *Sinanthropus* mandible (1936b), the position of the condyloid process varies widely, even in the few specimens preserved: in Mandible G I the process projects strongly outward while it is sharply bent inward in H I (cf. 1936b, Plate 15). The slight correction of this position thus seems justified.

In order to make the reconstruction of the originals as accurate as possible, casts of all those parts which could be left in their natural conditions were made, even if it resulted in asymmetries. This, for instance, is the case in the calvaria used as the base in which the right side of the asterion region projects more than the left one (Figs. 88 and 89), a condition partly due to some natural asymmetry partly to a post-mortem distortion which could not be adjusted any more.

Since the originals of the skull belong to a female individual the reconstruction represents an adult woman's skull with rather large dimensions. This fact must be borne in mind, for it implies that the characteristics of the *Sinanthropus* type are not as pronounced as they may have been in a male representative.

In describing the reconstructed skull I wish to stress that I shall refer here only to such features as have become more distinct and more impressive than they appear under the isolated conditions mentioned above. For the purpose of demonstrating the resemblances between the *Sinanthropus* skull and the anthropoids, on the one hand, and the dissimilarities between the skull and modern man, on the other, a skull of modern man (North Chinese) and that of a female gorilla (as representative of the anthropoids) have been placed beside the reconstructed *Sinanthropus* skull in lateral, frontal, occipital, vertical and basal aspects (Figs. 168–172), all oriented in the Frankfort Horizontal plane. One of the most striking peculiarities of the *Sinanthropus* skull in lateral view (Figs. 86 and 168) is the great length of its post-otic section. If a perpendicular is erected within the porion, the post-otic length almost equals that of the pre-otic length (94 : 100 or 48.5 per cent of the greatest length of the skull). This also occurs in hyperdolichocephalic skulls of modern man where the post-otic length can even considerably exceed (up to more than 52 per cent) the pre-otic one. But considering the fact that the post-otic length in anthropoids often is not more than one third of the greatest length of the skull (the nuchal crest excluded)—Fig. 168, A—, such a high percentage in the case of *Sinanthropus* is rather surprising. It must be taken into account, however, that the braincase is very low in

the latter, thus making the post-otic length appear much more pronounced than is true in high-vaulted skulls. The post-otic length in the reconstructed *Sinanthropus* skull is 102 per cent of the auriculobregmatic height while in the aforementioned skulls of modern man the ratio varies between 80 and 95.

The reconstruction reveals another interesting feature in connection with the post-otic length. In anthropoids (Fig. 168, A) the occipital contour bends directly upward behind the tympanic with the nuchal crest located high above the Frankfort Horizontal. In modern man (C) the line first goes downward but in no case is the inion region situated at a higher level than the Frankfort Horizontal. *Sinanthropus* (B) falls exactly between the two alternatives; the occipital contour first runs parallel to the Horizontal and then bends upward toward the torus which, however, clearly lies above the Horizontal. The degree of the downward expansion of the occiput in modern Man can easily be gauged by taking the height of the ramus of the mandible as scale. In gorilla (A) the deepest point of the occipital contour is on about the same level as the tip of the coronoid process, in *Sinanthropus* (B) the deepest point corresponds to that of the semilunar notch, in modern man (C), however, it is far below the notch, even in cases where the latter is rather deep as in the depicted one.

There construction, furthermore, shows the far projecting suprafacial ridges and the rather abruptly rising forehead; low in general and receding as a whole despite its well vaulted profile line. The profile line of the superior part of the face (glabella-prosthion) appears very long and the alveolar process convex and rather protruding. This prognathism is underlined by a protrusion of the entire maxilla, as especially indicated by the course of the inferior portion of the crista nasalis (cf. Fig. 168 A–C). The nasal bridge is relatively high and instead of an infraglabellar notch there is an evenly curved but not too shallow depression. The conditions are similar to those found in the Rhodesian skull.

The course of the zygomatic arch is of particular interest. As the free portion of the arch is not preserved, the accuracy, in so far as its thickness and special configuration is concerned, cannot be vouched for, but its direction and position can be ascertained since both ends are available. As was shown by Lebzelter (1913), in modern man the arch as a rule runs parallel to the Frankfort Horizontal and at the same level with its upper margin, following this line in general (Fig. 168, C). In anthropoids and monkeys this margin lies below FH and shows the greater deviation the lower the monkey ranges in the system (Fig. 168 A). According to Lebzelter, the upper margin always runs above the Frankfort plane in Australian and Melanesian while only in Bushman below it. *Sinanthropus* in this respect reveals the primitive pattern; the point where the margin continues into the frontal process of the malar bone—incisura zygomaticotemporalis—lies distinctly in accord with the height of the malar bone and the face, on the one hand, and the lowness of the braincase, on the other. In spite of the protrusion of the alveolar part of the maxilla the projection as a whole falls considerably short when compared with that of an anthropoid (cf. Fig. 168, A and B). One of the reasons for this difference is the manner in which the *Sinanthropus* face is attached to the skull base. The frontal portion of the alveolar process reaches further downward than the malar portion; there is no upward bending or a "Spee curve" as in anthropoids (Fig. 168, A) or modern man (Fig. 168, C). The mandible follows the same line in both its alveolar and basal planes. *Sinanthropus* strikingly resembles the Rhodesian Skull in this regard.

The profile curve of the muzzle differs characteristically from those of anthropoids and modern man. In the reconstructed skull the alveolar process of the maxilla constitutes the most

projecting component while the mandible recedes almost in a straight line from the incision to the gnathion. Since the teeth are strongly worn edge-to-edge bite conditions were supposed, otherwise an overbite would have been the correct assumption (cf. Weidenreich, 1937b). Despite the still chinless state of the mandible, the already advanced reduction of its alveolar process is evident; on the other hand, there is no resemblance to conditions of modern man, even in those cases where the latter show strong prognathism. In the North Chinese depicted in Figure 168 C there is only a slight degree of prognathism; but even in more pronounced cases the conditions would be the same, namely the development of an "incurvatio" immediately below the alveolar margin accentuating its projection and producing a more or less marked state of "prodenty." The maxilla of modern man is also equipped with such an "incurvatio"; as was described above, the so-called fossa canina is merely a specially located case of the general alveolar depression which characterizes the entire root area of the frontal teeth. In the lower jaw below the mandibular incurvatio the base thrusts forward as "mentum osseum." In principle the same is true for the maxilla. The anterior nasal spine is an equivalent to the chin and like the latter specific of the more advanced stages of human evolution; both features are completely missing in anthropoids. In *Pithecanthropus* the nasal spine is indicated as a slight median projection, it appears more developed in the Neanderthalians, but reaches its typical development in modern man although in widely varying degree. Thus, nasal spine and chin must be considered as fixed basic points of the jaws which become prominent if the primarily protruding alveolar processes undergo an increasing reduction in the course of human evolution (cf. Fig. 168, B and C).

The frontal view of the restored skull (Figs. 87 and 169 B) shows, as far as the braincase is concerned, all the peculiarities outlined above: greatest breadth at the level of the biauricular plane and gradual decrease toward the parietal tuberosity; a well developed sagittal crest with the parasagittal depression on either side, a low forehead and heavy suprafacial ridges. All of these properties of primitive hominids appear all the more specific if compared with the contrasting conditions in modern man (Fig. 169, C). Despite its length in lateral view (Figs. 86 and 168, B), the face is broad; this broadness is caused both by great bizygomatic and bigonic breadth. It is furthermore particularly marked by the breadth of the cheek bones and their frontal orientation. The alveolar part of the maxilla, however, appears narrow, notwithstanding its relative breadth obviously due to the deep notch which separates the body of the maxilla from the malar tubercle. That such an incisura malaris is characteristic of *Sinanthropus* was shown above. The frontal orientation of the malar bone can also be seen in lateral view (Fig. 86). As to the suprafacials the details of which were outlined above, attention is again called to the fact that their pronounced development makes the zygomatic process of the frontal bone the farthest lateral projection of the entire upper portion of the face while in modern man this part is taken by the frontomalare temporale (fmt; cf. Fig. 169, C). The nasal bridge is broad and short. Its breadth not only depends on the breadth of the nasal bones themselves but also on that of the frontal process of the maxilla. In correspondence therewith the anterior nares are wide and low. Their inferior border is a simple edge which does not rise above the level of the nasal floor. There is no indication of any kind of prenasal fossa or sulcus. Neither was there any nasal spine; the low, slightly pointed median crest evident in the restoration is the utmost that could be expected of this structure from what the fragment shows.

The orbits give the impression of being particularly low. As may be gathered from the figures (see next chapter), however, they are actually higher than they appear. The seeming lowness is due to the heavy supraorbitals, the slight curvature of the supraorbital margin and

particularly to the strong development of the supraorbital process which marks the lateral border of the supraorbital notch. The lateral margin is remarkable in that its utmost expansion is not reached within the middle or near the inferior corner but that it coincides with the frontomalare orbitale (fmo). Since the nasal bridge is short the medial orbital wall is low and, consequently, the nasolacrimal canal and the two crests which border it. For the position, configuration and size of the optic foramen, the upper and lower fissures and the neurovascular canals the reader is referred to the detailed description given above.

The occipital view of the reconstructed skull (Figs. 88 and 170, B) reveals, as far as the calvaria itself is concerned, not much more than the non-restored specimens do. But the attachment of the mandible accentuates the special form and lowness of the braincase, particularly when compared with that of modern man (Fig. 170, C). On the other hand, a comparison with the gorilla (Fig. 170, A) shows how much *Sinanthropus* agrees with the latter in breadth and lowness of the skull base and how much it deviates from the pattern of modern man. If again the height of the jaw is taken as a scale for gauging the degree of the downward expansion of the occiput in modern man, it will be found that the occipital view shows it much more impressively than the frontal one. In apes (A) the whole ramus, including the condyles are visible, in modern man (C) they are concealed by the occiput and the pars mastoidea while *Sinanthropus* (B) keeps the midline also in this regard. Moreover, in gorilla the whole occipital foramen is exposed while in *Sinanthropus* the opisthion only is recognizable and in modern man all is concealed by the squama of the occipital bone. Furthermore, in apes the inion, as marked by the nuchal crest, lies high above the foramen and close to the vertex; in *Sinanthropus*, however, it coincides with the opisthocranion and in modern man it is far below at the base of the skull.

The vertical view of the reconstructed skull (Fig. 89 and 171, B) shows the strongly developed suprafacial ridges, the relative narrowness of the frontal portion of the braincase and, in connection therewith, a pronounced postorbital constriction. The torus occipitalis is visible in its entire length. The angular tori stand out like sharp corners at the posterior ends of the temporal lines; no similar structures can be observed in modern man (C). In conformity with the special shape of the braincase the squama of the temporal bone and the squamous suture is discernible from above while in modern man they are completely covered by the bulging of the parietal bone. The small breadth of the braincase, together with the pronounced postorbital constriction and lateral projection of the suprafacials, make the zygomatic arch visible in its entire length. Thus *Sinanthropus* shows a distinct "phenozygy." As is evident from Figure 171 (C), this feature may also occur in modern man, although "cryptozygy" is more common here. In any case, it is certainly much more developed in *Sinanthropus* than it ever is in man. The nasal bridge is not or only slightly visible in vertical view and so is the upper jaw; in this respect *Sinanthropus* comes much closer to man than to anthropoids. The deviation from the pithecoid pattern, of course, is due to the already considerable reduction of the maxilla as the lateral view reveals (Figs. 86 and 168).

The reconstruction of the base (Figs. 172, B and 173) was confined to the parts actually preserved. Thus, a relatively large gap remains which embraces the entire center of the base, extending in sagittal direction from the posterior nares to the opisthion and in transverse direction from the region of the carotid canal of one side to that of the other. The view shows the elongated and narrow but rounded occiput, the extensive breadth within the tympanic and mastoid region and the postorbital constriction at the temporal fossa. Compared with a dolichocranial skull of modern man (Fig. 172, C) the occipital foramen seems to occupy a more posterior

position, a question, which will be discussed later together with the measurements. Yet there is one other striking contrast: the tympanic and the petrous crest of the *Sinanthropus* skull is oriented in a perfect transverse direction, as is true in anthropoids (cf. gorilla, Fig. 172, A) whereas in modern man (Fig. 172, C) the crest runs from in front and medially back and laterally (see above). The basal view, furthermore, shows the inward inclination of the mastoid process, the tegmen pori acustici and the deep and short mandibular fossa, all in contrast to the conditions in modern man (Fig. 172, C).

As to the face, the most conspicuous difference between the reconstructed skull and the New Britain (Fig. 172, A) is the protrusion of the supraorbital margins beyond the infraorbital ones. This, of course, is due to the bulkiness of the supraorbitals but also partly to the more pronounced recession of the infraorbital margin. However, such a feature may also occur in modern man. In R. Martin's textbook (1928), for example, the two skulls depicted in basal view (Martin's Fig. 419 and 420, p. 930) show the supraorbital margin to protrude beyond the inferior one while the skull of Figure 422 (p. 935) looks like the New Britain of my Figure 172, A. It is perhaps not purely accidental that the first two skulls belong to Mongolian races, one representing a Chinese, the other a Kalmuck while the third skull is that of a Swiss.

The forms of the palate and the dental arc of the reconstructed female skull fail to display any striking differences between *Sinanthropus* and modern man. Nevertheless, differences do exist. In *Sinanthropus* both structures are distinctly longer and narrower than in modern man (Fig. 172, B and C), although they fail by far to approach the exaggerated length and narrowness of the anthropoid maxilla (Fig. 172, A). In *Sinanthropus* the frontal teeth are arranged in a more rounded curve than is true in man where they usually form a more or less straight line. But it must be admitted that the form of the dental arc described by Campbell (1925, Pl. 26) as typical of adult male Australians displays the recorded characteristics of the arc in a rather more pronounced way than the reconstructed *Sinanthropus* skull does. However, as repeatedly stressed above, this skull represents a female individual, and there is evidence that males differ in this regard. Since there is no difference in the form of the maxillary and mandibular dental arcs the reader is referred to my study on the *Sinanthropus* mandible (1936b) in which all these questions have been discussed with the difference, negligible in this case, that it is the alveolar instead of the dental arc dealt with there.

Considered as a whole, no other aspect shows the general discrepancies between *Sinanthropus* and anthropoids, on the one hand, and his resemblance to man, on the other, as impressively as does the basal view (Fig. 172). This is, of course, due to the fact that the face of *Sinanthropus*, in this case represented by the maxilla only, is much smaller than that of the anthropoids and is more like that of modern man, according to the correlation of size which exists between braincase and face.

The suggestion rose that an attempt should be made to reconstruct the physiognomy of *Sinanthropus* on the basis of the reconstructed skull. The front of both braincase and facial skeleton shows very distinctive traits certainly expressed in the soft parts and, consequently, also in the physiognomy. The reconstruction thus promised to fulfill two possibilities: first, to give a general idea of the appearance of such a primitive hominid, and secondly, whether there may have existed certain specific traits indicating similar ones in the great racial mix-up of modern mankind.

Reconstructions of the physiognomy on the basis of skulls have repeatedly been carried out. The reader is referred in particular to Wilder's (1912) and Stadtmüller's (1922) papers which

also contain a complete bibliography. The first who tried to apply this method to early fossil man was E. Dubois (1902). But his reconstruction of the entire body of *Pithecanthropus erectus* with skull cap and a doubtful femur as the only substratum can scarcely be considered a serious contribution to our knowledge of this hominid type. The principle which guided Dubois in his reconstruction of the face is evident in the following phrase: "In a creature that after all that we know is intermediate between man and apes the nose must have been certainly intermediate between those of inferior races and anthropoids."

The physiognomy of the Neanderthal man was reconstructed almost simultaneously by von Eickstedt (1925) and McGregor (1926). In both cases a cast of the skull of La Chapelle-aux-Saints served as foundation on which layers of plastiline were spread, according to the supposed thickness of the soft parts. As guide for the thickness use was made of the results obtained by earlier investigators who had determined the thickness of certain regions of head and face in cadavers of different races. McGregor decided to use approximately "the average for well-nourished but not fat individuals." von Eickstedt chose the average of the thickness of the soft tissues of eight Melanesians of New Guinea and New Caledonia.

In reconstructing the head of *Sinanthropus* I followed McGregor's method (cf. McGregor's figures 3 and 4, p. 291) by inserting pins on the cast of the reconstructed skull at the critical points. These pins were cut at heights corresponding to the desired thickness of the soft parts. Only those points were chosen which had proved to be the most characteristic landmarks in previous reconstructions. von Eickstedt's figures were used but only as a general guide; for in our case we had to remember that, on the one hand, the head we were modelling belonged to a woman and, on the other, that the soft parts of a primitive hominid like *Sinanthropus* would probably have been fleshier than is true of a male of modern man, even of one of the most primitive race.

In Table XVIII the thickness of the soft parts of the *Sinanthropus* reconstruction have been listed side-by-side with those of von Eickstedt's reconstruction of the man of La Chapelle-aux-Saints.

The modelling of the head was carried out by Mrs. Lucille Swan who fulfilled the task with great skilfulness and understanding. As in all similar cases there is, of course, no indication as to the special appearance of eye, mouth, ear and hair. The racial character depends, however, to a considerable extent upon the peculiar shaping of these features. Lest we suggest a certain type, it was decided to make all these features "indifferent," that is to say, such as they appear in the majority of the representatives of modern mankind. Thus, the eye shows only a very faint upward slanting of the slit, the lips are thin and not fleshy and the hair is almost straight and only slightly undulated. The ear, negligible for our purpose, is partly concealed under the hair. The form of the nasal bridge is given by the underlying skeletal parts, only the shape of the fleshy part could be conjectured. In this case a medium broad nose with the tip directed slightly upward was chosen to correspond to the width of the nasal aperture.

Figures 174–179 illustrate the reconstructed head. Figures 174–176 show the head (A) with the skull (B) on its side, both reduced to the same size; Figures 177–179 display the same head with the skull exposed on its left half. One of the most characteristic features is the contour of the profile as represented in Figures 174 and 177. The outline differs from both McGregor's and von Eickstedt's reconstructions of Neanderthal man. Compared with the first one (McGregor, 1936, Fig. 7, p. 292) the supraorbitalis protrude much more in proportion to the lower forehead. This is in perfect accord with the appearance of the skull. In von Eickstedt's re-

TABLE XVIII

Thickness of Soft Parts of the Reconstructed Head of a Sinanthropus Woman (in mm.)

Region	*Sinanthropus*	Eickstedt's La Chapelle-aux-Saints
Vertex	8.0*	—
Middle of the forehead	7.5*	2.5
Glabella	6.0	4.8
Inion	8.0*	—
Nasion	6.0	5.0
Rhinion	3.0	3.5
Anterior nasal spine (akanthion)	15.0	13.0
"Philtrum"	11.0	9.0
Incision	9.0	9.0
Chin	11.5	10.0
Gnathion (beneath chin)	7.5	4.0
Eyebrow (middle)	6.0	8.3(?)
Base of the mandible in front of Masseter	8.0	5.8
Zygion	8.0	6.0
Middle of ramus of the mandible	21.0	21.0
Gonion	13.5	10.0
Frontomalare temporale	7.0	—

* Scalp plus pelage.

construction the eyebrows appear as two entirely isolated protuberances which certainly was not the case in *Sinanthropus*; neither does it seem to me to be correct for the man of La Chapelle-aux-Saints. The latter had a high nasal bridge and a deep infraglabellar notch. This, too, is different from *Sinanthropus*. As to the mouth, von Eickstedt's reconstruction exhibits a mild prognathism while there is no indication of any protrusion of the upper lip in McGregor's model. In both cases the nose projects further than the mouth, while the mouth is more muzzle-like in *Sinanthropus*, with the result that a vertical, tangent to the upper lip, cuts the nose only at a very short distance behind its tip. Since the contour of the mandibular front runs almost in a straight line from the lip to the gnathion region, and similar conditions exist in anthropoids, there seems to be no justification for a distinct furrow below the lip such as is indicated in the Neanderthal reconstructions.

Two additional differences concern the sides of the face. First, the entire cheek region of *Sinanthropus* reaches farther forward and—as revealed by the frontal view (Figs. 175 and 178)—more laterally than is true in the case of La Chapelle-aux-Saints; and secondly, the angle of the mandible is everted and thus appears fleshier than in the latter. Both these features fully conform to the corresponding structures of the skeleton. The most striking peculiarity, however, to which attention has already been called elsewhere, is the thickness of the neck. The length of the anterior-posterior diameter of the neck is quite obvious in Figure 174; yet because the contour of the nape is concealed by hair, this presentation strikes the eye less than the model with the exposed skull (Fig. 177). From the bend of the throat to the point where the nape continues into the occiput the thickness amounts to 190 mm. In *Sinanthropus* the line of the nape apparently did not turn forward below the occipital protuberance as it does in modern man and is also portrayed in both reconstructions of Neanderthal man mentioned above. In *Sinanthropus* the opisthocranion coincides with the inion or, in other words, the center of the occipital torus is the most posterior landmark of the skull; the nuchal plane where the cervical muscles

take their origin begins immediately below. In modern man the inion which marks this point is situated rather below the opisthocranion and at the same time much more toward the front (see following chapter); the contour of the neck turns, therefore, forward beneath the opisthocranion. Such nuchal incurvation did not exist in *Sinanthropus*; his conditions rather resemble those of the great apes which, however, were certainly more bull-necked. In the skull of La Chapelle-aux-Saints the opisthocranion does not really coincide with the inion but lies above the latter, although not at a great distance from it. The bull-neck can, therefore, not have been very pronounced in this case. Yet Boule claimed that the man of La Chapelle-aux-Saints carried his head in a stooping manner; his deduction was derived from the particular development of the spinous processes of the cervical vertebrae, which suggests the existence of bulky cervical muscles. How *Sinanthropus* did appear in this respect cannot be determined since the decisive parts of the vertebrae are lacking in our collection. Yet the configuration of the occipital portion of the skull seems to confirm Boule's suggestion. The stooping carriage of the head is indicated in all of the figures (Figs. 174–179), notwithstanding its orientation in the Frankfort Horizontal plane.

The frontal view of the reconstructed head (Figs. 175 and 178) exhibits all of the peculiarities of the skull so far as they can be expressed in the soft parts. This is particularly true of the forms of the forehead and face. The forehead is low and narrow and increases continuously in breadth from the top down to the zygomatic region, where the greatest breadth is reached. The sagittal crest of the skull is not represented, for it is assumed that the hair completely conceals this structure as it actually is the case in living individuals.

The specific traits of the face have already been described. The face appears short and broad as a whole; the cheek bones, in particular, are high and salient such as found in the Mongol race of today. The breadth and shortness of the neck is also evident in frontal view but especially distinct in the three-quarter profile aspect (Fig. 179).

As was already pointed out above, I had no intention of exaggerating the primitive features of the physiognomy. I was, therefore, especially careful not to commit the error usually made by lay artists when reconstructing the portrait of primitive man; namely to apply savage appearance and dishevelled headdress as a sign of primitiveness. Genuine primitive traits should be sufficiently indicated without any emotional distortions of mimical muscles or disordered hair.

C. Metrical Characters and Craniograms
I. Prolegomena on Methods

In criticizing the anthropological technique used in studies of comparative character Washburn (1942) states: "Many technical difficulties which do not appear serious in the comparison of living races loom as major obstacles in the comparison of non-human primates." The reason is obvious. "The measurements were devised for the description of certain aspects of human anatomy and are applied to more or less similar parts of non-human primates." Washburn asks: "In adapting these measurements to animals with very different anatomical characteristics, should the same landmarks be used or should they be adapted to measure comparable morphological entities? Are the measurements supposed to describe more or less of the same morphology or simply the distance between points, regardless of what lies between?" Twenty years ago (1922) in the introductory part to my publication on the human foot I also raised the question as to the value of the usual anthropological measurements. "The mere measuring and the mere description of features with the only purpose to state differences are of no help. One

should always know in advance why a certain measurement is taken and what has been measured. There are many standard measurements which are entirely irrelevant from the viewpoint of comparative anatomy, while others are omitted which would be of great value if correctly taken."

The difficulties which Washburn outlined not only apply to non-human primates but are encountered when dealing with fossil man. In most of these cases the obstacles are further exaggerated by the deficiency of the material. When Schwalbe first attempted to make comparative anatomical investigation of the *Pithecanthropus* skull cap (1899) and, subsequently, of that of Neanderthal (1901) his efforts were directed towards the establishment and definition of a basic horizontal plane with distinct landmarks which could serve for the determination of the height. On account of the defective state of the specimens involved only one plane came in question, namely the plane defined by the glabella in front and the inion in the rear. Since neither the Trinil nor the Neanderthal Skull had an occipital protuberance at which Broca placed the inion, Schwalbe identified the latter with the center of the occipital torus in its quality as the point which projects farthest backward. But he did emphasize that he would have preferred to take the nasion as the anterior point if not for the fact that it was missing in *Pithecanthropus*. Sollas (1908) refused to accept Schwalbe's glabella-inion-line or plane as a metrical base for hominid calvariae on account of the instability of the inion and the alteration of its position in the course of human evolution. For the same reason Keith (1927) introduced as a substitute the sub-cerebral plane which he laid through the zygomaticofrontal and the parietomastoid sutures.

The example of the inion shows that in dealing with fragmentary skulls the choice of landmarks depends entirely on the nature of the fragments. Keith's sub-cerebral plane can, of course, not be applied when the defining points are missing. On the other hand, difficulties caused by instability of landmarks will be encountered in all cases in which the transformation of the skull constitutes the main problem of investigation. Thus, the only way open under such circumstances is to use, if possible, only those landmarks which have been proved as relatively stable and to ascertain the manner and degree of their dislocations. This is also the best method in defining the rules which may regulate the transformation itself.

The controversy over the inion which played a great rôle in the literature on the metrical qualities of early man is a typical example that too much pedantry, on the one hand, and disregard of the true meaning of the measurements, on the other, direct anthropometric methods. According to Broca's original definition (1875), the inion indicates the demarcation between the cerebral and the cerebellar region of the skull. This, however, holds good only for modern man and even here does not prove to be correct in all of the cases. The inion has been identified by Broca with the external occipital protuberance, "a prominence sometimes very pronounced, sometimes reduced to a minute tubercle and frequently completely missing." Schwalbe, as was just mentioned, used the inion because in *Pithecanthropus* and Neanderthal man it coincides with the most posterior point of the outer surface or, in other words, because it can serve as opisthocranion. However, since a great variability exists in the exact localization and development of the external occipital protuberance which renders the determination of the inion rather difficult in some cases, R. Martin (1928) defined the inion as the point where the two nuchal superior lines meet in the midsagittal plane. If there is instead a more or less developed occipital torus the inion must consequently be placed at the inferior margin of this elevation. It follows from Martin's definition that he considers the inion merely as an accidental muscular mark but not as a substantial element in the construction of the braincase. Buxton and Morant (1933) in placing the inion at the vertex of the occipital ridge which marks the change in direc-

tion between the occipital and nuchal planes reinstalled the inion in the position formerly assigned by Schwalbe.

The inion as a landmark on the outer surface of the calvaria belongs to the system of "superstructures" which in lower hominids are represented by the occipital torus and connected structures (cf. Weidenreich, 1940b). The torus, however, is not merely a muscular mark, as I have shown (confer also the following chapter), although it serves as an attachment for muscles. Since a distinct lower margin of the torus failed to develop in *Pithecanthropus* (Skulls I and II) as well as *Sinanthropus*, at least in Skulls III and XI, the inion had to be transferred to the center of the torus and such location had to be maintained also in those cases in which the lower margin is more distinct. From the comparative viewpoint it is rather irrevelant which of the possible points may be designated as inion, as far as modern man is concerned. For the inion indicating the uppermost limit of the nuchal plane changes its position in the course of human evolution. In anthropoids the inion is only little below the level of the lambda; but as the braincase enlarges and the bulk of the cervical musculature decreases, it shifts downward until it reaches a definite position at the base of the skull—at a distance from the opisthion which is only about one third of the total length of the lambda-opisthion arc.

The opisthocranion, on the other hand, which in anthropoids and man marks the occipital pole of the calvaria shifts upward in precisely opposite direction. In great apes it falls on the nuchal plane of the occipital bone, in modern man on the occipital plane. Opisthocranion and inion coincide in *Pithecanthropus, Sinanthropus* and in some forms of the Neanderthal group.

For these reasons neither inion nor opisthocranion are suitable as landmarks for a plane intended to serve as a stable base for the determination of the height of the calvaria—if more convenient ones are available. The glabella at the opposite end of such a plane is less objectionable although this landmark, too, alters its position. However, it does not shift upward or downward but only in an anterior-posterior direction, and, therefore, does not affect the outcome unless the lines or planes concerned are used for profile orientation. In any case, the nasion is preferable to the glabella, for it indicates not only the boundary between forehead and face proper but also the anterior end of the floor of the cranial cavity. Indeed, it is the point where braincase and face join. This is true of man as well as anthropoids. Washburn (1942) objects to the nasion as landmark in determining the height of the face of non-human primates: "If one measures from nasion . . ., upper facial height wanders meaninglessly with the variations of the nasal bones." It is true, difficulties may be met with if we adhere too strictly to the definition of the nasion as the "crossing point of the nasofrontal suture and the mid-sagittal plane" (Oppenheim, 1926) or as "the upper end of the internasal suture, where it meets the frontal bone" (Wilder, 1920). But if nasion is merely considered the crossing point between the mid-sagittal plane and the medianward prolongations of the frontomaxillar sutures all of the difficulties that may arise from the conditions of the nasal bones in anthropoids can be evaded. Topographically —and this is the essential point—it is the transverse suture between the frontal bone and the nasal skeleton which marks the boundary between braincase and face in both man and anthropoids.

The opisthion is preserved in two *Sinanthropus* skulls (Skulls XI and XII) while in one skull (Skull III) the breakage comes very close to it. In *Pithecanthropus* Skull II the opisthion is just recognizable at the broken end of the occipital bone. Such being the case, it permits the use of the opisthion as the posterior landmark for a basal plane of the *Sinanthropus* and *Pithecanthropus* skulls. As in all of the five *Sinanthropus* specimens where the greater part of the calvaria is preserved the nasion also is intact or can be determined without effort, a plane through nasion

and opisthion is available for comparative purposes.   This actually is a basal plane because it corresponds almost perfectly to the cerebral base of the skull or the base of the brain from the anterior-inferior end of the frontal lobe to the posterior-inferior end of the cerebellum.   In a mid-sagittal diagram (Fig. 180) the nasion-opisthion line represents the basal line of the calvaria in its entire extension and all essential landmarks necessary for the determination of form and height of the vault can easily be brought in relation to that line.   This line, moreover, has the great advantage of being restricted to the braincase and, therefore, completely independent of the face and the Frankfort Horizontal.

There is a second basal line which is generally considered as the basal line proper, that is, the nasion-basion line or the cranio-basal length.   However, this length does not include the posterior end of the skull base, for the line terminates in front of the occipital foramen which, in man, is certainly, as already stressed by Cleland (1870), a part of the base.   In addition, the length of the nasion-basion line depends, as will be proven later, to a large extent upon the size and depth of the face so that it is more justifiable to regard it as the basal line of the face (Fig. 180).

There is still another essential landmark which cannot be used in dealing with primitive hominids if one holds too strictly to the official anthropometric instructions, namely the "euryon." R. Martin (1928) defined the euryon as the most prominent point of the lateral wall of the calvaria, which can only be determined by measuring the greatest breadth.   But from the greatest breadth the root of the zygomatic arch, the supramastoid crest and the entire neighbouring region above the external auditory meatus are expressly excluded.   In modern man there is indeed no difficulty in finding such a point above the excluded zone; for the wall of the braincase reaches it farthest lateral prominence on the temporal squama or the parietal bone.   But there is no such prominence in *Sinanthropus* since the greatest breadth of the braincase coincides with the salients of the barred zone.   Davidson Black (1931) thus distinguished not less than three "maximum breadths" and an additional one of similar character.   The first—No. 13 of his list— is called "maximum parietal breadth" corresponding to Morant's "B."   Black adds: "this diameter falls far back on the specimen (Skull of Locus E), lying between points just above the squamous suture and immediately anterior to the lower ends of the parietal portion of the inferior temporal lines."   It follows from this description that the "euryon" chosen by Black coincides with the most salient point of the torus angularis.   Black's second maximum breadth— No. 14 in his list—is designated as "maximum breadth above supramastoid crests" and considered identical with the "euryon" of No. 8 of Martin's list.   This diameter, according to Black, falls on the temporal squama just above the crista.   Black's third maximum breadth is known · as "intercrestal breadth"—his No. 15—and taken on the supramastoid crest, that is to say, near the mastoid portion about 10 mm. in front of the parietal notch.   The biauricular breadth the position of which does not differ from the usual one is taken by Black at the "auriculare." But Black introduced one other breadth which he termed "intersquamous breadth"—No. 24 of Black's list—and defined as follows: "This diameter is taken in the same plane as the biauricular breadth but the terminals fall upon the temporal squamae immediately above the zygomatic roots."   However, this breadth is almost identical to Black's "maximum breadth above the supramastoid crests," the difference amounting to 1 mm. only.   Yet none of Black's "maximum breadth" actually corresponds to the maximum breadth in modern man.   The reason is self-evident.   The shape of the *Sinanthropus* braincase differs in principle from that of modern man, as shown above; the "greatest breadth" falls upon the base just within the excluded zone, while the diameter decreases constantly toward the vertex.   Similar conditions exist in anthropoids.

The supramastoid crest which appears as a continuation of the united temporal and nuchal crests dominates the entire region in question.

Which of Black's various maximum breadths of *Sinanthropus* now correspond to the standard measurements of man and what can be done to determine the maximum breadth of anthropoid skulls with some degree of accuracy? St. Oppenheim (1926) supplies the following instruction: "The eurya are to be determined at the superior limit of the diploic spaces of the temporalia." This seems a rather Pythian advice. How can this limit be defined without the aid of skiagrams? In any case, Oppenheim places the euryon of anthropoids at the temporal squama somewhere below the squamous suture and above the supramastoid crest. In *Sinanthropus* and similar primitive hominid skulls only one way is open for the determination of the "maximum breadth," as already indicated by Black, namely to take the measurements of diverse breadths and, if it is necessary to insist on a single one, to take the average of all of them. In conformity therewith, I accepted Black's "maximum intercrestal breadth" and "maximum parietal breadth" but changed the latter to what it really represents, namely the "torus angularis breadth." The two other breadths, the "maximum breadth above supramastoid crests" and the "intersquamous breadth" are entirely superfluous, all the more so as it is impossible to define their "eurya." Instead, in each case one other breadth should be taken the eurya of which can be placed without difficulties; namely the temporoparietal breadth—No. 8 of R. Martin's list. According to G. Schwalbe (1901, 1902) this breadth represents the "true" breadth in apes. R. Martin defines the temporoparietal breadth as being the direct transverse distance between the superior margins of the temporal squamae where their lateral projections reach the maximum. To be more precise, the measurement should be taken at the points where the interporial coronal contour meets the squamous suture. In primitive hominids such as *Sinanthropus* the greatest breadth still falls below these points, even if the crest region proper is disregarded. In the majority of cases, however, the average of the four breadths in question covers all the needs for comparison, particularly such for computing length-breadth and breadth-height indices (see later).

There remains one other essential landmark which, as far as primitive hominids are concerned, requires a more correct definition, namely the porion. The porion is "the uppermost point in the margin of the auditory meatus" as interpreted by Wilder (1920), or in R. Martin's (1928) sense: "the point at the superior margin of the auditory porus that is situated vertically above its center." In modern man no mistake is possible in this regard for the edge of the tympanic which surrounds the porus reaches laterally to about the same parasagittal plane as the surface of the mastoid. But as described above, this is quite different in *Sinanthropus* and *Pithecanthropus* where the edge fails to extend so far outward. When the porion is placed vertically above the center of the porus, its position moves inward to a point somewhere on the roof of that structure I termed "tegmen pori acustici." In *Sinanthropus* Skull III there is a fissure at the floor of the porus, in Skull XI an indent, in the remaining cases as in the two just mentioned the anterior or the posterior lip projects further than the other. In all these and similar cases the porion should be placed on the roof of the tegmen and on a parasagittal plane tangent to the most projecting part of the porus edge. For the determination of the Frankfort Horizontal only the height of the porion is important but for the "interporial breadth" (Black's No. 27, my list No. 29) it is essential to know how far medially the porion lies in relation to the "auriculare."

In dealing with early man the entire system of determining the profile angles of the face should be also revised. Its chief weakness lies in its exclusive relation to the Frankfort Hori-

zontal and, therefore, absolute independence of the braincase itself whereas an intimate correlation exists between these two main constituents of the skull with regard to their size and position (cf. Weidenreich, 1941b). If we wish to know how far the face or its parts project beyond a vertical line drawn from the nasion—this is what we really mean when speaking of prognathism —, the nasion must be taken as one of the landmarks, and as the second we must take the most prominent point of that part whose exact position we wish to determine. Since the greater portion of the face lies beneath the base of the skull and projects beyond the base to a variable extent, the third point of the triangle must be placed on the basion as the posterior end of that portion of the skull base which can fairly be brought into connection with the face. In other words, the so-called facial triangle determined by nasion, basion and one of the median landmarks of maxilla or mandible (nasospinale, prosthion, gnathion) represents the only geometrical construction which will adequately meet all of the requirements for a correct and satisfactory measurement. As I have already mentioned briefly and will prove exhaustively later, the position of the basion and, therefore, also the length of the nasion-basion line, depends to a great extent upon the development of the face. Which point of the maxilla or mandible will be selected as apex of the triangle depends upon the special purpose. In order to determine the degree of prognathism of the maxilla the prosthion has to be taken as apex, in the case of the mandible the gnathion. When dealing only with the so-called alveolar prognathism, nasospinale and incision replace prosthion and gnathion.

The superior facial triangle (Fig. 180) is formed by the nasion-basion line (cranial base) as base, the nasion-prosthion line (superior facial height) as one side and the basion-prosthion line (superior facial length) as second side. The total facial triangle is formed again of the nasion-basion line as base, and the nasion-gnathion (total facial height) and basion-gnathion lines (inferior facial length) as the two remaining sides. More recently, the facial triangle, especially the superior one, has been recommended, in particular by Rivet (1909), as the best construction to determine the degree of prognathism of the maxilla but, strangely enough, Rivet considered the angle at the prosthion the most adequate one for this purpose and not the angle at the nasion. R. Martin (1928) in referring to the angles of the triangle remarks that "they have been in many cases computed as expression of the development of the jaw; but it is not advantageous to bring the nasion-prosthion line in relation to the prosthion-basion line because a more prognathous or more orthognathous profile can be feigned by a greater or smaller superior facial height." In executing the construction of the facial triangle on a sheet of paper (Fig. 180), it is apparent at first glance that Martin is only right in so far as Rivet's recommendation of the prosthion angle is concerned. If, however, the angle at the nasion is used as an indicator of prognathism, the length of the nasion-prosthion line or, in other words, the height of the face has not the slightest influence upon the width of the nasion angle.

The fact is that the angle at the nasion becomes only greater the longer the superior facial length (basion-prosthion line) or the deeper the face is or, in other words, the more the maxilla projects. On the other hand, the angle at the prosthion becomes smaller the longer the superior facial height (nasion-prosthion line) or the higher the face is. The angle at the basion is independent of the length of the basion-prosthion line, that is to say, it remains unchanged regardless of the extension of the prosthion, provided the latter keeps on the same horizontal plane. If, however, the height of the face increases, the basion angle increases proportionally to the reduction of the angle at the prosthion. The same conditions, of course, exist if instead of the prosthion the nasospinale, the incision or the gnathion is taken as landmark of the facial section

concerned. The facial triangle with the angle at the nasion as indicator of prognathism and that at the prosthion as indicator of the facial height is in every respect far superior to the profile angles generally accepted in anthropometry.

In addition, there are two further advantages in application. As exposed above, the nasion-opisthion line represents the true base line of the braincase and the nasion-basion line the true base line of the face. Figure 180 reveals that of the two lines the former is always the longer one, as the distance between basion and opisthion represents the length of the occipital foramen. But there is a distinct angle at the nasion where the two base lines meet. The width of this angle does not depend upon the length of the foramen only but also upon its direction. If the basion lies on the same horizontal plane as the opisthion, the angle appears small; if, however, the basion falls below the opisthion (implying that the foramen faces backward) or if the opisthion falls below the basion (and the foramen faces forward), the angle at the nasion increases. Indeed, it is nearly twice as large in anthropoids than it is in hominids, having an average of 10° in the former but decreasing to 2° in recent man. If the nasion-basion line is assumed as relatively stable, the decreasing width of this angle infers a downward shift of the opisthion or a downward expansion of the occiput and, consequently, a change in the direction of the occipital foramen.

The second advantage of the facial triangle is to be found in the ease with which the measurement can be handled. There is no need of halfing the skull or even of drawing the mid-sagittal diagram with the aid of a diagraph. It is sufficient to determine the length of the desired lines on the skull with a caliper or slide compass and to transfer them to a sheet of paper (cf. Rivet, 1909). All of the angles discussed can be measured if the sides of the triangles are drawn in. Even the construction of the triangle itself can be omitted if only interested in obtaining the angles. In the latter case, the lengths of the sides are marked with the aid of a compass on "polar coordinate paper" obtainable on the market, and the degree of the angle can be read off directly.

The question raised by Washburn, whether in measuring animals with different anatomical characteristics the same landmarks should be used as those standardized for man or should the landmarks be adapted to the measurement of comparable morphological entities, can, I believe, be answered only in the latter way. If, for instance, heights of braincases of hominids and gorilla are compared, it would be absurd to place the vertex in the latter case at the top of the sagittal crest of an adult male individual, for the heights obtained hereby may even match such of recent man. In such cases, there is no other choice but to refrain from using inadequate specimens; these will have to be replaced by female individuals in which no crest has developed or, if it has, is so low that its height proves negligible. This holds good for all measurements and landmarks of the skull in which superstructures take an important part but do not constitute in any way the goal of the investigation. In some examples listed above I have shown how difficulties arising from seeming unconformities of objects can be mastered. This, however, is not always possible. The investigator must adapt the method he considers best for his purpose; he should not hesitate to disregard standard measurements and apply new ones. The only disadvantage he faces in such a case is the dearth in the literature of comparable figures which he must provide then from his own investigations.

II. THE TABLES

Tables XIX–XXI contain all the measurements of the calvariae of *Sinanthropus* Skulls II, III, X, XI and XII. The measurements of the smaller skull fragments are given in the general

description or will be referred to in individual cases when discussing the variability of the *Sinanthropus* skulls. Tables XXIX and XXX contain the measurements of the face. Since only fragments of individual facial bones have been preserved, the measurements of the face as a whole have been taken from the reconstructed skull; measurements of the facial fragments will be found in the description of the individual bones.

In Tables XIX–XXI the measurements of *Pithecanthropus* calvariae I and II have been added, those of Skull I in part computed according to Weinert's reconstruction. *Pithecanthropus* Skull III is so fragmentary that the specimen is useless for general measurements. I have also omitted *Pithecanthropus* Skull IV from the list. Since this skull is crushed and the entire frontal bone missing (cf. Weidenreich, 1940b) measurements can be made only of the reconstructed skull. Those measurements are recorded occasionally in discussions of special questions, but because of their uncertainty I consider it safer not to include them as documented data in cases where absolute accuracy is required.

Tables XXII and XXIII contain the measurements of *Homo soloensis* calvariae I, V, VI, IX, X, and XI. They are taken from the casts and are limited to measurements which give a fair picture of the general and special form of this hominid type, such as would permit of comparison with *Sinanthropus, Pithecanthropus* and the Neanderthalians.

Tables XXIV and XXV contain the measurements of the following calvariae of the Neanderthal group: Rhodesian, La Chapelle-aux-Saints, Neanderthal (Düsseldorf), Spy I, Gibraltar (adult), La Quina (adult), Tabūn I, Skhūl V, Ehringsdorf. In all these cases the measurements have been taken from the original papers or computed from drawings by the authors or taken directly from casts.

In Tables XXVI and XXVII the minimum-maximum values and the averages of the main measurements of the various hominid forms essential for comparison have been set side-by-side, and have been completed by the addition of corresponding figures of anthropoids and modern man taken, for the most part, from R. Martin's textbook (1928). New measurements, used for the first time in this study, have been taken directly from the skulls; since it is not the purpose of this paper to furnish a great number of figures as material for more extensive comparison I have confined my comparisons to a limited number of skulls, selected to give a fairly reliable cross-section of the possible variations. For the anthropoids the figures required were chiefly those of the size and shape of the braincase itself; therefore, skulls were selected in which the superstructures were not too heavily developed and so did not obscure the form of the braincase proper and the landmarks indicating the limits of the individual bones. Male gorillas and orang-utangs with pronounced crests have been excluded; also those with sutures so radically obliterated that their course could no longer be determined. The figures for the three anthropoid genera have not been given individually but as an "anthropoid average", because I found that the individual variations of the measurements in which I was especially interested show about the same range in one genus as those of all three genera together. In modern man I have followed, in principle, the same practice as I applied in dealing with anthropoids. For the measurements which had never before been recorded I used fifteen to twenty skulls of quite different races: Whites, Negroes, Mongols, Australians, Melanesians; hyperbrachycephalics and hyperdolichocephalics; skulls with large capacity and skulls with small. The average obtained in this way can, therefore, despite the small number of measured specimens, be said to come very close to the average obtained by measuring a much larger number of more uniform skulls. The truth of this assumption can be deduced from the data given in the list which shows that

the average computed from my figures is so close to that computed from the minimum-maximum values of the various racial groups, recorded by other authors, that the difference is negligible.

Tables XXIX and XXX contain the measurements of the face of anthropoids (average), *Sinanthropus* (reconstructed specimen), five Neanderthalians (Rhodesia, La Chapelle-aux-Saints, Gibraltar, Tabūn I, and Skhūl V), and modern man (average). In the cases of the anthropoids and modern man the figures have been obtained principally in the same way as for the calvaria. Measurements referring to the mandible of *Sinanthropus* are included only in so far as they concern the skull as a whole, and have been taken from the re-constructed skull; for other measurements the reader is referred to my special paper on the *Sinanthropus* mandible (1936b).

The measurements listed in the tables are arranged in three groups: (1) linear measurements (M), (2) angles (A), and (3) indices (I). Measurements of the calvariae are marked with a C; those of the face with an F. For example, the letters CA refer to the angles of the calvarium; the letters FI to the indices of the facial skeleton. Every measurement has its own number indicated by the serial number in the first column. The linear measurements, angles, and indices do not have individual serial numbers, but are distinguished from each other by the capital letter indicating the nature of the measurement. In the arrangement of these measurements I have followed R. Martin's list; however, since many of the measurements recommended in this list have been omitted as useless for our purposes, and additional ones have had to be specially created, the serial numbers of the list differ from those of Martin's list. To facilitate their identification, I have added a separate column with Martin's numbering, and have designated the newly-introduced measurements by special symbols to define the indices briefly. These new measurements concern, in particular, the height of the vault above the base-line (nasion-opisthion) with the bregma, vertex, lambda, opisthocranion, and inion as landmarks. The numbers 13–16 indicate the distances from the nasion at which the foot-points of the verticals stand when drawn from the landmarks to the base-line. They correspond, therefore, to some of the foot-points of the verticals, drawn from the same landmarks to the glabello-opisthocranion line (nos. 11 and 12). I have designated the latter by the symbols bp^1 and lp^1, and the former by bp^2, lp^2, ip, and op. To the heights (nos. 44–48) above the base-line have been assigned the symbols bh^2, vh, lh, oph, and ih; to the height of the bregma above the glabello-opisthocranion line (not recorded in R. Martin's list) the number 40 and the symbol bh^1. The height of the vertex above this line is called the calvarial height and is indicated by Martin's number 22a. Another newly introduced measurement is that of the biangular breadth, which is designated by the number 18 and the symbol tb.

In order to facilitate understanding of the meaning of the indices, the relation of the two measurements has been indicated in a separate column by R. Martin's numbers and, in the case of the newly introduced ones, by the adopted symbols, as recorded above.

In addition, the essential lines and angles used for the measurements, are drawn in the craniograms (Figs. 180–190), and designated by the serial numbers that they have in the tables, so that they can easily be identified in case of doubt.

In the lists dealing with *Sinanthropus* I have recorded all the measurements considered worth taking by earlier authors. The serial numbers given to the individual measurements refer in all cases to these lists. In the lists of the *Homo soloensis* and Neanderthal skulls, and those with distinctive features serving for craniological comparison the measurements have been restricted to really essential ones. Omissions in the serial numbers in the lists, therefore, indicate that the measurements concerned are recorded in the *Sinanthropus* lists but have been passed

over in the remaining lists as being less important. The lists containing the indices have a special column, indicating by means of Martin's numbers or, if the measurements are newly introduced, by their special symbols the relationship they represent.

All the figures referred to in the following discussion are taken from Tables XIX to XXVII.

III. METRICAL AND GRAPHIC APPEARANCE OF THE CALVARIA

1. Size

The size of the calvaria can be determined by measuring the greatest diameters of length, breadth, and height or by computing the cranial capacity.

The maximum length of the *Sinanthropus* calvaria varies from 188–199 mm., with an average of 193.6 mm. These measurements apply only to the five best-preserved skulls; there is, however, evidence that the real range is considerably greater, extending beyond these minimum and maximum values. Skull V, of which only the temporal bone and parts of the adjacent bones are preserved, has a glabella-opisthocranion length of at least 205 mm. (Weidenreich, 1936/37) while Skull VI, represented by four small fragments of the frontal, parietal, and temporal bones, was not much larger than 165 mm. The individual range of the maximum length in modern man, including all races, is 158–203 mm. with an average of 185.6 mm. The *Sinanthropus* figures show that the variation is nearly as great and certainly not essentially smaller than in modern man but that the average length is greater in *Sinanthropus*. In the anthropoids the length of the *Sinanthropus* calvaria is equalled only by that of the male gorilla, of which the cranial length measures 193 mm. for the coast-type, and 188 mm. for the mountain-type, according to Coolidge (1929). Orang-utang and chimpanzee fall considerably behind these figures even in the case of the big males. But it must be borne in mind that the glabella-inion length of a male gorilla is not really equivalent to the glabella-opisthocranion or inion length of *Sinanthropus*, as I pointed out in the prolegomena to this chapter, since the superstructures of the gorilla skull are much more prominent.

The maximum breadth of the *Sinanthropus* calvaria varies from 137 to 143 mm. with an average of 141 mm. As was explained above, this measurement is the "average maximum breadth." Whether the extent of the breadth-range was similar to that of the length cannot be ascertained since the fragments of Skulls V and VI do not permit a fair estimate of the maximum breadth. In modern man the corresponding measurement varies from 124 to 157 mm. with an average of 133.6 mm. The biauricular breadth provides a safer basis for comparison. This breadth varies in *Sinanthropus* from 141 to 151 mm. with an average of 145.5 mm. In Skull V, which is not included in this series, the probable biauricular breadth is estimated to have been between 148 and 155 mm.; that is to say, near to or more than 150 mm. In modern man the biauricular breadth varies from 115 to 132 mm. with an average of 121 mm. This is obviously much less than in *Sinanthropus*. But in the anthropoids (except for male gorilla and orang-utang) the average is 120 mm. or about the same as in modern man. In male gorilla the average biauricular breadth is much greater reaching almost 150 mm.

The total height of the *Sinanthropus* calvaria (basibregmatic height) can only be estimated since in no specimen is the basion preserved. In the reconstructed skull the height measures 115 mm. This is considerably less than in modern man with an approximate range of 110 to 150 mm. and an average of 134 mm. In the anthropoids the height varies between 85 and 100 mm. Coolidge (1929) records 114 mm. as average for the male gorilla. However, this figure does not

TABLE XIX

Linear Measurements (CM) of Sinanthropus and Pithecanthropus Calvariae

No. CM	Calvarial Measurement	Symbols and Key Numbers*	Sinanthropus					Pithecanthropus	
			II	III	X	XI	XII	I[1]	II
					A. Length				
1	Maximum: *g-op(i)*	1(2)	194?	188	199	192	195.5	(183)	176.5?
2	Horizontal projective	1a	—	184	197.5	190.5	193.5	(182)	174?
3	Ophyron-occipital: *on-op(i)*	1b	—	176	190	181	183	170	162
4	Nasion-opisthocranion (inion): *n-op(i)*	1d	—	184	194	185	192	(179)	—
5	Glabella-lambda line: *g-l*	3	183? 180?B	172	186	169	174	(167)	159?
6	Nasion-lambda line: *n-l*	3a	180 177?B	170	184	166	175	(165)	—
7	Inner skull	4	—	156–157	173	167	168	153–154	148
8	Nasion-basion line: *n-ba*	5	—	—	—	rest. 105.5	—	—	—
9	Nasion-opisthion line: *n-o*	5(1)	—	144?	—	145	147	(144)	134?
10	Horizontal occipital	6(2)	—	48?	—	47	50	(41)	42
11	Bregma position projected to *g-op*	bp¹W	81?	74	74	79.5	78	(77.5)	64?
12	Lambda position projected to *g-op*	lp¹W	178?	167	181	165	169	—	153
13	Bregma position projected to *n-o*	bp²W	—	52	—	56	62	—	44
14	Lambda position projected to *n-o*	lp²W	—	148	—	142.5	154	—	134
15	Inion position projected to *n-o*	ipW	} —						
16	Opisthocranion position projected to *n-o*	opW		178	—	181	182	—	164.5
					B. Breadth				
17	Temporo-parietal	8c	—	133	138?	135	139?	(126)	131
18	Torus angularis	tbW	127	131	137	136	140	—	134
19	Max. intercristal	XV B	—	144?	150?	145	147?	134?	140
20	Average "maximum"	(8¹)W	—	137.2	143	139.8	141	(130?)	135
21	Inner skull	8(2)	—	122	128?	128	129	126	121
22	Least frontal: *ft-ft*	9	84?	81.5	89	84	91	85	79
23	Postorbital	9(1)	106?	88	98?	93	95	(91)	83?
24	Greatest frontal: *co-co*	10	108?	101.5	110?	106	108	92?	102?
25	Stephanion: *st-st*	10b	—	78?	—	81	103	(92)	69?
26	Biauricular: *au-au*	11	—	141	147	143	151	(135)	129?
27	Biasterionic: *ast-ast*	12	103	117	111?	113	115	(92?)	120?
28	Bimastoid: *ms-ms*	13	—	106?	—	103?	—	—	102
29	Interporial: *po-po*	XXVII B	—	122.6	124?	120	128?	—	114
30	Lateral interglenoidal	XXVIII B	—	131?	—	126?	130?	—	117
31	Medial interglenoidal	XXIX B	—	82?	—	84	92?	—	71?
32	Stylo-mastoid	XXXII B	—	91.4	100?	88	92?	—	—
33	Distance between temporal lines	ltbW	—	90	94	86	104?	—	67

* Symbols and key numbers to Martin's (1928) and other lists; B, after Davidson Black; W, after Weidenreich.
[1] Figures taken from Weinert; those within brackets are calculated.

TABLE XIX (*continued*)

No. CM	Calvarial Measurement	Symbols and Key Numbers*	Sinanthropus					Pithecanthropus	
			II	III	X	XI	XII	I¹	II
			C. Height						
34	Basi-bregmatic	17	—	—	—	rest. 115	—	(105)	105?
35	Opisthion above FH	19	—	105?	106.5?	104	103	(92)	92
36	Auricular-bregmatic: *po-b*	20	—	96.5 (93.5B)	106	94	101.5	(94)	89
37	Auricular above FH	21	100 (97?B)	95 (92.7B)	105	93.5	100	(92)	92
38	Auriculo-lambda: *po-l*	XI B	—	91	100	93	93.5	—	87.5
39	Inner skull	IH	—	105	—	102	110	104	93
40	Bregma above *g-op(i)*	bh¹W	78?	68	80	66	72.5	—	60.5
41	Calvarial above *g-op(i)*	22a	79?	71	82	67	74.5	61	66
42	Calvarial above *n-op(i)*	22	83?	75	85	71.5	81	66	—
43	Calvarial above *g-l*	22b	57?	47	57.5	45	49.5	(40)	41
44	Bregma above *n-o*	bh²W	—	89	—	90	95	—	78
45	Vertex above *n-o*	vh W	—	103	—	100	101	—	88
46	Lambda above *n-o*	lh W	—	83	—	81	83	—	74.5
47	Opisthocranion above *n-o*	oph W	—	47	—	53	41	—	37
48	Inion above *n-o*	ih W	—	47	—	53	41	—	37
			D. Circumferences, arcs and chords						
49	Horizontal circ.: *on⌒on(op)*	23a	—	504?	520	507	518	—	481
50	Max. horizontal circ.: *g⌒g(op)*	23	—	557?	582?	556?	560?	(525)	526?
51	Auriculo-bregmatic arc: *po⌒po(b)*	24	—	277	310	280	280	(258)	262
52	Median sagittal arc I *n⌒op*	25a	—	263	293	271	277	(264)	234
53	Median sagittal arc II *n⌒o*	25	—	321	—	332	337	(304)	302?
54	Nasion-bregma arc *n⌒b*	26	123 (120B)	115	129	122	124	(100)	107?
55	Glabella-bregma arc: *g⌒b*	(26)	115	110	120	112	110	(100)	90
56	Nasion-bregma chord: *n-b*	29	113 (109B)	102	115	106	113	(100)	90?
57	Glabella-bregma chord: *g-b*	(29)	110	100	112	104	107	98	88
58	Bregma-lambda arc: *b⌒l*	27	112 (110B)	100	113	92	102.5	91	94
59	Bregma-lambda chord: *b-l*	30	104	94	106	86	91	87.5	91
60	Lambda-opisthion arc: *l⌒o*	28	—	106?	—	118	118	(103)	101?
61	Lambda-opisthion chord: *l-o*	31	—	80?	—	86	86	(78)	75
62	Sagittal arc—pars glabellaris front.: *n⌒sg*	26(1)	28	25	28	26	32	(26)	—
63	Chord—pars glabellaris front.: *n-sg*	29(1)	22	22	25	21	28	(19)	—
64	Sagittal arc—pars cerebralis front.: *sg⌒b*	26(2)	93	88	96	97	91	85	73?
65	Chord—pars cerebralis front.: *sg-b*	29(2)	82.5	83	94	89.5	88	83.5	71
66	Sphenion-asterion arc: *sphn⌒ast*	27(1)	l 107?	r 109? l 106?	—	r 108? l 103?	107	—	r 102? l 91?
67	Sphenion-asterion chord: *sphn-ast*	30(2)	l 100	r 99? l 96?	—	r 99? l 99?	l 101	—	r 88? l 85?
68	Lambda-asterion arc: *l⌒ast*	27(3)	r 90? l 90?	r 90 l 88	r 93 l 88	r 99? l 85?	r 92 l 100	—	r 98 l 99

TABLE XIX (*continued*)

No. CM	Calvarial Measurement	Symbols and Key Numbers*	Sinanthropus					Pithecanthropus	
			II	III	X	XI	XII	I¹	II
		D. Circumferences, etc. (continued)							
69	Lambda-asterion chord: *l-ast*	30(3)	r 83? l 83?	r 81 l 77	r 85 l 78	r 84? l 77?	r 87 l 87		r 85 l 83
70	Lambda-opisthocranion (inion) arc: $l \frown op(i)$	28(1)	—	49	51	50	55	—	47
71	Lambda-opisthocranion (inion) chord: *l-op(i)*	31(1)	—	47	49	48	52.5	(43)	45
72	Opisthocranion (inion)-opisthion arc: $op(i) \frown o$	28(2)	—	60?	—	67	60	(57)	52
73	Opisthocranion (inion)-opisthion chord: *op(i)-o*	31(2)	—	58?	—	63	57	(53)	48
		E. Capacity							
74	Cranial capacity in cc.		1030	915	1225	1015	1030	935	775

represent the "approximate height of the braincase," as the author claims, for the measurement was not taken vertically to the Frankfort Horizontal, but rather diagonally extending, as he states, from the basion to the "point where the sagittal crest forks in front." This point is a good deal forward of the bregma, and even the bregma itself does not fall on a vertical plane above the Frankfort Horizontal but in front of it. Therefore, the total height of the calvaria of the male gorilla does not exceed the 100 mm. limit of the females and the other anthropoids.

The size of the *Sinanthropus* calvaria, measured by the greatest length, the maximum breadth, and the total height, appears to be almost equal to that of the average of modern man but greater than in any of the anthropoids. If the three diameters are summed up, the sum amounts to 449 in *Sinanthropus* and 453 in modern man. But a closer examination reveals that the slight superiority of the latter is due only to its greater height; *Sinanthropus* has greater length and breadth. Compared with the anthropoids as a whole *Sinanthropus* undoubtedly has the larger braincase, even when his superstructures are included in the measurements.

The circumferences of the skull show the same variations as the diameters. The maximum horizontal circumference of *Sinanthropus* varies from 557 to 582 mm. with an average of 564 mm.; the auriculo-bregmatic arc from 277 to 310 mm. with an average of 287 mm.; and the total median sagittal arc from 263 to 293 mm. with an average of 276 mm. In modern man the variation of the three arcs ranges from 440 to 599 mm., 286 to 344 mm., and 343 to 398 mm. and the corresponding averages are 507, 311, and 372 mm. The maximum horizontal circum-ference of the *Sinanthropus* skull is, therefore, much greater than the average of modern man (564 mm. as against 507 mm.) while the transverse and the sagittal arcs are superior in modern man (287 and 276 mm. as against 311 and 372 mm.). The reason for these differences is obvious. The horizontal circumference embraces all the basal prominences (suprafacial, angular and occipital tori and the supramastoid crest) which are pronounced in *Sinanthropus* but negligible in modern man while the transverse and sagittal arcs rise to a much higher vertex in modern man, the diameters of their bases having about the same length. Compared with the anthropoids

the transverse and sagittal arcs and the horizontal circumference are considerably greater in *Sinanthropus*; the horizontal circumference has an average measurement of only 391 mm. in the three great apes.

In comparing the size of the *Sinanthropus* skull with that of *Pithecanthropus*, the difficulty arises that only *Pithecanthropus* Skull II can furnish reliable measurements. Skull I is defective and, therefore, can be used only with considerable reservation. But judging from the parts which are intact its general form does not differ essentially from the much more complete Skull II, except for its somewhat greater dimensions in length and breadth. Skull IV, on the other hand, is a larger and much heavier specimen than Skulls I and II. The maximum length of the three *Pithecanthropus* skulls varies from 176 to about 200 mm. and the average maximum breadth from 135 to about 146 mm. If *Sinanthropus* Skulls V and VI are included the range of length and breadth is greater in *Sinanthropus*. On the whole, the *Pithecanthropus* skull is shorter and narrower than the *Sinanthropus* skull. This is true also for the total height of *Pithecanthropus*. In *Pithecanthropus* Skull II the height measures about 105 mm., and in Skull I, as estimated by Weinert, also 105 mm. Skull IV is certainly not higher, despite its greater dimensions in length and breadth. In Skull III only the height of the parietal bone, that is, the height of the skull-cap above the temporo-parietal suture can be measured. It is exactly the same as in Skull II.

TABLE XX

Angular Measurements (CA) of Sinanthropus and Pithecanthropus Calvariae

No. CA	Calvarial Angles	Symbols and Key Numbers*	Sinanthropus						Pithecanthropus[1]	
			II	III	X	XI	XII	Average	I	II
1	Frontal profile: *m-g* ∠ *g-(op)i*	32, a	—	62°	63°	61°	56°	60.5°	(47.5°)	55°
2	Frontal inclination I: *b-n* ∠ *n-op(i)*	32, 1	45°?	44°	46.5°	42°	44°	44.3°	(41°)	—
3	Inclination of frontal squama: *b-g* ∠ *g-op(i)*	32, 2	45°?	42°	45°	38°	42.5°	42.5°	(38°)	42.5°
4	Inclination of pars glabellaris: *sg-n* ∠ *n-op(i)*	32, 3	—	73°	70°	55°	65°	65.8°	(63°)	—
5	Inclination of pars cerebralis: *sg-b* ∠ *n-op(i)*	32, 4	—	39°	41°	38°	37°	38.7°	(37.5°)	—
6	Frontal curvature (angle of frontal bone flatness): *m-n* ∠ *n-b*	Morant	18°	22°	21°	24°	16°	20.2°	—	—
7	Occipital inclination (upper scale) I: *l-op(i)* ∠ *op(i)-n*	33(1a)	—	67°	70°	60°	64°	65.2°	(65°)	
8	Occipital inclination II: *l-op(i)* ∠ *op(i)-g*	33(1b)	—	65°	68°	57°	61°	62.7°	(62°)	62.5°
9	Opisthion-opisthocranion (inion) (lower scale): *o-op(i)* ∠ *op(i)-n*	33(2a)	—	39°?	36°?	43°	34°	38°	—	41°†
10	Occipital curvature: *l-op(i)* ∠ *opi(i)-o*	33(4)	—	106°	104°?	105°	98°	103.2°	(108°)	103°
11	Frontal inclination II: *b-n* ∠ *n-o*	—	—	59°	58°?	59°	57°	58.2°	—	60°
12	Inclination of whole occipital: *l-o* ∠ *o-n*	—	—	93.5°	99°?	88°	92°	93.1°	—	92°
13	Calvarial base: *n-op(i)* ∠ *FH*	37	—	7°	3°	3°	4°	4.2°	(2°)	—
14	Cranial base: *ba-n-o*	—	—	—	—	rest. 5°		5°?	5°W	—
15	Inclination of occipital foramen: *n-ba-o*	—	—	—	—	rest. 159°		159°?	162°W	—

* To R. Martin's and other lists.
[1] Figures taken from Weinert; those within brackets are calculated.
† *Pithecanthropus* IV.

Table XXI

Indices (CI) of Sinanthropus and Pithecanthropus Calvariae

No. CI	Calvarial Indices	Symbols and Key Numbers*	Sinanthropus						Pithecanthropus	
			II	III	X	XI	XII	Average	I	II
1	Length-breadth	(8¹)/1(2)	—	72.3	71.4	72.4	72.6	72.2	—	76.5
2	Inner length-breadth	8(2)/4	—	78.2	74.1	76.7	76.2	76.3	81.5	82.0
3	Length-height	17/1(2)	—	—	—	rest. 59.6	—	(59.6)	—	—
4	Length-auricular height	21/1(2)	51.5	50.5	52.8	48.7	51.2	50.9	—	52.2
5	Length-opisthion height	19/1(2)	—	56.0	53.6	54.2	52.7	54.1	—	52.1
6	Breadth-height	17/(8¹)	—	—	—	rest. 75.6	—	(75.6)	—	—
7	Breadth-auricular height	21/(8¹)	—	69.6	74.0	67.2	70.3	70.3	—	68.1
8	Bregma height above *g-op(i)*	bh¹/1(2)	40.2	36.2	40.2	34.4	37.1	37.6	—	34.2
9	Calvarial height above *g-op(i)*	22a/1(2)	40.7	37.8	41.2	34.8	38.0	38.5	33.3	37.4
10	Calvarial height above *n-op(i)*	22/1d	—	40.7	43.7	38.6	42.2	41.3	36.9	—
11	Bregma height I: above *n-o*	bh²/5(1)	—	61.8	—	62.0	64.6	62.7	—	58.2
12	Vertex height above *n-o*	vh/5(1)	—	71.6	—	69.0	67.7	69.4	—	64.2
13	Lambda height above *n-o*	lh/5(1)	—	57.6	—	55.8	56.4	56.6	—	55.6
14	Opisthiocranion height above *n-o*	oph/5(1)	—	32.7	—	36.6	29.7	32.3	—	27.6
15	Inion height above *n-o*	ih/5(1)	—	32.7	—	36.6	29.7	32.3	—	27.6
16a	Bregma position above *n-o*	bp¹/5(1)	—	36.1	—	38.6	42.2	38.9	—	32.9
16b	Vertex position above *n-o*	vp¹/5(1)	—	64.5	—	66.8	67.7	66.3	—	66.0
17	Lambda position above *n-o*	lp¹/5(1)	—	102.8	—	98.3	104.8	102.0	—	100.0
18	Occipital length I	6(2)/1a	—	26.1	—	25.2	25.9	25.7	—	24.1
19	Occipital length II (*op(i)* behind *o* in relation to *n-o*)	op/5(1)	—	23.6	—	24.8	23.8	24.0	—	(22.6)
20	Sagittal cranial curvature	5(1)/25	—	44.8	—	43.6	43.6	44.0	—	44.4
21	Transverse cranial curvature	11/24	—	50.9	47.4	51.1	54.8	50.8	—	45.6
22	Frontal breadth	9/10	—	80.3	80.9	79.3	84.2	81.2	92.4	77.4
23	Transverse fronto-parietal	9/(8¹)	—	59.7	62.6	60.4	64.1	61.7	—	58.5
24	Transverse parieto-occipital	12/(8¹)	—	86.2	78.3	81.3	81.0	81.7	—	89.0
25	Transverse postorbital-biauricular	9(1)/11	—	62.4	66.7	65.0	62.9	64.2	—	66.4
26	Lower parietal breadth	8c/11	—	94.4	93.8	94.4	92.2	94.5	—	101.5
27	Upper parietal breadth	ltb/11	—	63.8	63.8	60.2	68.9	64.2	—	51.8
28	Fronto-parietal (*arc*)	27/26	91.3	88.6	87.6	75.4	76.5	83.9	—	—
29	Fronto-occipital (*arc*)	28/26	—	95.7	—	96.0	95.3	95.7	—	—
30	Parieto-occipital (*arc*)	28/27	—	108	—	127	124	119.7	—	105.3
31	Fronto-sagittal arc	26/25	—	34.7	—	36.7	36.8	36.5	—	—
32	Parieto-sagittal arc	27/25	—	30.7	—	27.6	28.2	28.8	29.9	33.4
33	Occipito-sagittal arc	28/25	—	33.1	—	35.2	35.1	34.5	—	35.3
34	Frontal curvature	29/26	91.8	90.5	89.2	86.9	91.2	89.9	—	—
35	Flatness of frontal bone (subtense (*st*) to *n-b/n-b*)	st/29	16.7	18.6	14.8	16.1	15.9	16.4	—	—
36	Glabellar curvature	29(1)/26(1)	78.7	88.0	89.3	81.0	87.6	84.9	—	—
37	Cerebral curvature	29(2)/26(2)	88.8	94.3	98.0	92.3	96.7	94.0	98.4	97.2
38	Glabello-cerebral	29(1)/29(2)	26.7	26.5	26.6	23.5	31.8	27.0	—	—
39	Parietal curvature	30/27	93.1	94.0	94.0	93.5	95.7	94.1	96.0	95.8
40	Occipital curvature	31/28	—	74.2	—	74.5	72.8	73.8	—	75.0
41	Upper scale curvature	31(1)/28(1)	—	96.0	96.0	96.0	95.4	95.8	—	95.8
42	Lower scale curvature	31(2)/28(2)	—	96.6	—	94.0	95.0	95.2	—	92.3
43	Nasion-basion length	5/5(1)	—	—	—	rest. 72.6	—	(72.6)	—	—

* Symbols and key numbers to R. Martin's (1928) and other lists.

There is, therefore, every indication that the total height of the *Pithecanthropus* skull does not surpass 105 mm. This is less than in *Sinanthropus* whose average height is about 115 mm. If we disregard Skull IV, the circumferences of the *Pithecanthropus* skull are, in all three dimensions, about 7 per cent smaller than in *Sinanthropus*. Skull IV which is very low has a transverse circumference equal to that of the *Sinanthropus* skulls; the other two circumferences cannot be determined with accuracy.

TABLE XXII

Linear Measurements (CM) Taken on Casts of Ngandong Skulls (Homo soloensis)

CM	Calvarial Measurements	Symbols and Key Numbers*	Skull I	Skull V	Skull VI	Skull IX	Skull X	Skull XI	Average
	A. Length								
1	Maximum: *g-op(i)*	1(2)	197	219.5	193	202	204.5	202	209
2	Horizontal projective	1a	193	215	188	197	202	196	197.7
4	Nasion-opisthocranion (inion): *n-op(i)*	1d	190	212	192.5	—	202	199	198.7
5	Glabella-lambda line: *g-l*	3	186	198	174	180?	182	177	182.8
6	Nasion-lambda line: *n-l*	3a	183	195	179?	—	183	178	183.6
7	Inner skull	4	161	175	c. 153	c. 164	c. 159	c. 157	161
8	Nasion-basion line: *n-ba*	5	—	—	113	—	—	114	113.5
9	Nasion-opisthion line: *n-o*	5(1)	142	162?	152	—	154	157	153.4
10	Horizontal occipital (*o-op*)	6(2)	53	60?	46	47	50	48	50.7
11	Bregma position projected to *g-op*	bp¹	84	84.5	68	75	81	72.5	77.7
12	Lambda position projected to *g-op*	lp¹	181	192	167	—	177	166	176.6
13	Bregma position projected to *n-o*	bp2	66	60	57.5	—	67	56.5	61.4
14	Lambda position projected to *n-o*	lp2	165.5	170.5	159	—	161.5	153	162
15	Inion position projected to *n-o*	ip }	187	206?	189	—	199	196	195.4
16	Opisthocranion position projected to *n-o*	op }							
	B. Breadth								
17	Temporo-parietal	8c	142	144	140	145	152	141	146
20	Average maximum	(8¹)	138	145	141	156?	153	143	146
21	Inner skull width	8.2	130	138	129	137	138	129	135
26	Biauricular	11	133	151	141	163	154	145	148
33	Distance between temporal lines	ltb	117	116?	119?	106	110	109	112.8
	C. Height								
34	Basi-bregmatic	17	118?	131?	123?	123?	118?	123	122.5
35	Opisthion	19	111	112?	103	107	91	106	105.0
36	Auricular (bregma)	20 }	108	109	105	106	111	105.5	107.4
37	The same above FH	21 }							
39	Inner skull	IH	103?	108	109?	105?	100?	109?	107
40	Bregma	bh¹	82	76.5	73	74	78.5	76	76.7
41	Calvarial above *g-op*	22a	84	80.5	78	77.5	80	80	78.8
44	Bregma above *n-o*	bh²	100	102.5	96	—	100	95	98.7
45	Vertex above *n-o*	vh	106	113.5	104	—	102	103	105.7
46	Lambda above *n-o*	lh	78	93.5	82	—	77	90	84.1
47	Opisthocranion above *n-o*	oph }	31	50	34.5	—	34	36	36.3
48	Inion above *n-o*	ih }							

TABLE XXII (*continued*)

CM	Calvarial Measurements	Symbols and Key Numbers*	Skull I	Skull V	Skull VI	Skull IX	Skull X	Skull XI	Average
	D. Circumferences, arcs and chords								
51	Auriculo-bregmatic arc: po⌒po	24	280?	305	275	283	295	285	287.2
52	Median sagittal arc: n⌒op(i)	25	296	309	287	290?	292	289	293.8
53	Median sagittal arc: n⌒o	25a	356	381?	338	345?	354	346	355
54	Nasion-bregma arc: n⌒b	26	139	136	122	—	135	122	130.8
56	Nasion-bregma chord: n-b	29	120.5	120	112	—	120	112	116.7
58	Bregma-lambda arc: b⌒l	27	106	117	107	103?	105	102	107.4
59	Bregma-lambda chord: b-l	30	101	111	102	99?	102	97	102
60	Lambda-opisthion arc: l⌒o	28	111	128?	109	115?	114	122	116.8
61	Lambda-opisthion chord: l-o	31	81.5	94?	82	88	78	106	88.2
	E. Capacity								
74	Cranial capacity (calculated)		1035	1255	1035	1135	1055	1060	1100

* Symbols and key numbers to Martin's (1928) and other lists.

In the Ngandong skulls the maximum length is considerably greater than that of *Sinanthropus*. Skull V has a length of 219.5 mm. and is the longest of the fossil skulls known. It comes very close to being the longest human skull ever on record. The average maximum breadth exceeds even that of *Sinanthropus* (146 mm. as against 141 mm.), and the same is true of the total height (122.5 as against 115 mm.). Of the average circumferences I did not note the horizontal but only the transverse and sagittal ones. The sagittal circumference exceeds the corresponding circumference of *Sinanthropus* (355 mm. as against 330 mm.); the transverse is of exactly the same length (both measuring 287 mm.). Compared with *Pithecanthropus* the Ngandong skulls are considerably larger in all dimensions.

No attempt to determine the size of the calvaria by measuring the lengths of the main diameters and arcs can, of course, furnish more than a general idea of its real shape even if the most bulging superstructures are excluded. The only measurement which can indicate its actual size is the volume of the cranial capacity. This capacity is, in the case of *Sinanthropus*, smaller than the outer form of the calvaria suggests not only because of the heaviness of the superstructure but also because of the thickness of the cranial wall in general. If, for instance, the maximum length and the maximum breadth are compared with the inner length and breadth of the skull the average difference in length will total 28 mm. (194 mm. against 166 mm.), and in breadth 17 mm. (141 mm. against 124 mm.). Or, if the capacity of the skull of modern man is calculated on the basis of the sum of the maximum length, maximum breadth, and auricular height, according to Lee-Pearson's method, a skull with the sum of L + B + H = 433 and a length-breadth index below 77.5 will have a capacity of 1196 cc. However, the average *Sinanthropus* skull with the same dimensions has an average capacity of only 1042 cc., that is 150 cc. or 12.7 per cent less, apparently due in great part to the greater thickness of its cranial walls. The thickness and architectonic structure of the *Sinanthropus* skull will be discussed in detail in the next chapter to which the reader is referred.

The cranial capacity of the five best-preserved *Sinanthropus* skulls has been computed. The method applied consisted in making of endocasts as accurate as possible; then in constructing the missing parts in proportions which correspond to those of the intact skulls, always with the best-preserved as model; and finally in determining the volume of the endocast by measuring its displacement of water. To make this possible the endocasts were made of plaster impregnated with paraffin after drying. In each case the single parts of the endocasts were thoroughly checked for exact fitting in the original skull. This method takes much time but is the only one that yields reliable results in cases where the base or the walls are more or less defective. The capacity of the five skulls ascertained in this way varies from 915 cc. (Skull III) to 1225 cc. (Skull X) with an average of 1043 cc. There is, however, every evidence that the variability is much greater. As was shown above, Skull V was longer than the other four; it is also broader, but I am not sure whether it is higher, too. Since the thickness of its walls does not surpass that

TABLE XXIII

Calvarial Angles (CA) and Indices (CI) of the Ngandong Skulls (Homo soloensis).   (Taken from Casts)

CA	Angles	Symbols and Key Numbers*	Skull I	Skull V	Skull VI	Skull IX	Skull X	Skull XI	Average
	Angles								
1	Frontal profile	32a	63°	54°	66°	61°	66°	62°	62°
2	Frontal inclination I	32, 1	46°	55°	48.5°	—	46°	48°	48.7°
3	Inclination of frontal squama	32, 2	43°	41°	47°	54°	44°	46°	45.8°
6	Frontal curvature	—	23°	19.5°	20°	—	22°	18°	20.5°
8	Occipital inclination II	33(1b)	73°	61°	64°	61°?	59°	59°	62.8°
10	Occipital curvature	33(4)	101°	100°?	102°	100°	91°	95°	98.2°
11	Frontal inclination II	—	56°	59°	59°	—	56°	58°	57.6°
12	Inclination of whole occipital	—	108°	97°	96°	—	100°	89°	98°
14	Angle of cranial base: *ba-n-o*	—	7°	—	7°	—	—	7°	7°
15	Inclination of the occipital foramen: *n-ba-o*	—	155°	—	154°	—	—	155°	154.7°
	Indices								
1	Length-breadth	(8¹)/1(2)	70.2	66.2	73.3	76.7	74.7	70.8	72.0
2	Inner length-breadth	8(2)/4	81.4	78.6	84.3	83.7	86.7	82.3	83.7
3	Length-height	17/1(2)	59.9	59.8	63.8	59.8	57.6	60.4	60.2
4	Length-auricular height	21/1(2)	54.8	49.8	54.5	52.4	54.2	52.3	53.0
5	Length-opisthion height	19/1(2)	56.3	51.2	53.4	53.0	44.3	52.6	51.8
6	Breadth-height	17/(8¹)	85.5	90.4	87.3	78.8	77.2	86.2	84.2
7	Breadth-auricular height	21/(8¹)	78.4	75.3	74.6	74.5	72.6	74.0	74.9
8	Bregma-height I above *g-op(i)*	BH/1(2)	41.7	34.9	37.7	36.7	38.3	37.6	37.8
9	Calvarial height above *g-op(i)*	22a/1(2)	42.6	36.8	40.4	38.3	39.0	39.8	39.5
11	Bregma height above *n-o*	bh²/5(1)	70.3	63.4	63.2	—	64.8	60.5	64.4
12	Vertex height above *n-o*	vh/5(1)	74.6	70.2	68.5	—	66.3	65.5	69.0
13	Lambda height above *n-o*	lh/5(1)	54.8	57.7	54.0	—	50.0	57.2	54.7
14	Opisthocranion height above *n-o*	oph/5(1) ⎫	21.8	30.9	22.7	—	22.1	22.9	24.1
15	Inion height above *n-o*	ih/5(1) ⎭							
16	Bregma position (bp²): above *n-o*	bp²/5(1)	46.5	37.0	37.8	—	43.5	36.0	40.2
16a	Vertex position (vp): above *n-o*	vp²/5(1)	75.5	66.0	65.2	—	53.2	63.0	64.6
17	Lambda position (lp²): above *n-o*	lp²/5(1)	116.6	105.2	104.6	—	104.9	97.5	105.7
18	Occipital length I	6(2)/1a	27.4	28.0	24.5	23.8	24.7	24.5	25.5

TABLE XXIII (*continued*)

CI	Angles	Symbols and Key Numbers*	Skull I	Skull V	Skull VI	Skull IX	Skull X	Skull XI	Average
	Indices (continued)								
19	Occipital length II (*op*, *i* behind *o* in relation to *n-o*)	op/5(1)	−31.5	−33.0?	−24.5	—	−29.0	−25.0	−28.7
20	Sagittal cranial curvature	5(1)/25	35.4	42.4	45.0	—	43.5	45.4	42.3
21	Transverse cranial curvature	11/24	47.5	49.5	51.3	57.2	52.2	51.8	51.6
26	Lower parietal breadth	8c/11	106.8	95.4	99.4	89.1	98.8	97.3	97.8
27	Upper parietal breadth	ltb/11	88	77	84.5	65.2	71.4	75.3	76.9
28	Fronto-parietal (arc)	27/26	76.3	86.0	87.8	—	77.9	83.6	82.5
29	Fronto-occipital (arc)	28/26	79.8	94.2	89.5	—	84.6	100.0	89.6
30	Parieto-occipital (arc)	28/27	104.8	109.3	102.0	112.6	108.5	119.6	109.5
31	Fronto-sagittal (arc)	26/25	39.3	35.8	35.9	—	38.1	35.5	36.9
32	Parieto-sagittal (arc)	27/25	29.9	30.8	31.4	29.9	29.6	29.7	30.3
33	Occipito-sagittal (arc)	28/25	31.3	33.7	32.1	33.3	32.1	35.5	32.8
34	Frontal curvature	29/26	86.5	88.3	91.7	—	89.0	91.8	89.5
35	Flatness of the frontal bone (subtense (*st*) to *n-b*: *n-b*)	st/29	19.9	15.8	16.9	—	19.2	15.2	17.4
39	Parietal curvature	30/27	95.5	95.2	95.6	96.3	97.3	94.2	95.7
40	Occipital curvature	31/28	74.1	73.3	75.2	76.4	68.4	87.0	75.7
43	Nasion-basion length	5/5(1)	—	—	70.6	—	—	72.6	71.3

* Symbols and key numbers to Martin's and other lists.

of Skull III, the thickest of them all, although it belonged to a juvenile individual, the capacity of Skull V may have been somewhat greater, perhaps reaching the 1300 cc. mark. On the other hand, Skull VI is certainly considerably smaller than Skull III. Taking into account the fact that its walls are thinner than those of the Skull III (cf. Weidenreich, 1936/37; Table I, p. 445) I estimate its capacity to be not more than 850 cc. Thus, the range of the volume of the*Sinanthropus* braincase is found to be 850 to 1300 cc. with an average of 1075 cc. In modern man the volume varies individually from 900 to 2100 cc. when abnormally small and abnormally large skulls are not included; the average is about 1350 cc. For the diverse racial groups the average varies between 1125 and 1600 cc. Von Bonin (1934) arrived at a much higher figure. According to this author, the average amounts to 1447.2 cc. He stated that the high mean was "undoubtedly influenced by the preponderance of Europeans in the sample" he dealt with, and, I might add, to the preponderance of males. *Sinanthropus* with an average of little more than 1000 cc. (1043 or 1075 cc.), therefore falls far below the lowest mark of modern mankind. In the anthropoids, on the other hand, the cranial capacity varies from 300 to 585 cc. with an average of 415 cc. The largest braincase ever measured is that of a male gorilla with a capacity of 623 cc. This is still much less than the smallest capacity of the *Sinanthropus* skulls even if we assume that the estimate of 850 cc. for Skull VI is its real capacity.

Pithecanthropus undoubtedly had a smaller cranial capacity than *Sinanthropus*. The Trinil cap (Skull I) is in all dimensions distinctly smaller than *Sinanthropus* Skull III but its walls are thinner. The completed endocast on sale is not sufficiently reliable to be used as a basis for determination, since the restored basal parts evidently were too large. As I have shown elsewhere (1936a), the capacity cannot have been appreciably greater than 900 cc. As for the capacity of *Pithecanthropus* Skull II, I must confess that I was mistaken when I first considered

it to be not smaller than 850 cc. (1938a). This estimate was based on the photographs and measurements given by von Koenigswald in his first publication on the skull (1937). Since that time I have had an opportunity to study the original and the endocast made in the interim by von Koenigswald. After the restoration of the non-preserved basal and frontal parts I determined its capacity, by means of the method described above, to be 745 cc. This is a little more than von Koenigswald's first estimate showed but less than my first guess. *Pithecanthropus* Skull III is too incomplete to permit an estimate of its capacity. This is possible, however, in the case of Skull IV despite its bad condition. As I have reported elsewhere (1940b), the construction of this skull was accomplished by adjusting the crushed parts and completing the missing frontal region. Length, breadth, and total height can thus be determined with a fairly good approximation to the original conditions. Moreover, since the thickness of the cranial walls is directly measurable, except for the missing frontal bone, the capacity can be computed. With an inner length of 152 mm., an inner breadth of 135 mm., and an inner height of 86 mm. the volume totals

TABLE XXIV

Calvarial Linear Measurements (CM) of Neanderthalians and Related Forms

CM	Calvarial Measurements	Symbols and Key Numbers*	Rhodesian	Neanderthal	Spy I	La Chapelle-aux-Saints	Gibraltar	La Quina (adult)	Ehringsdorf	Tabūn I	Skhūl V	Min.-Max.	Average
					A. Length								
1	Maximum: g-op(i)	1	210 (i)	199 (i)	202 (i)	208	193	203	196	183	192	183–210	198.4
2	Horizontal projective	1a	207	186	—	206	190	203	194	183	192	183–207	194.4
4	Nasion-opisthocranion	1d	202	192	199	207	—	201?	188	180	182	180–207	193.9
5	Glabella-lambda line: g-l	3	196	185	187	194	180?	183?	181.5	174	182	174–196	184.7
6	Nasion-lambda line: n-l	3a	191	184	187	192	179	183?	177	170	174	170–192	181.8
7	Inner skull	4	173	175	—	186	168	—	171	161	167	161–186	171.6
8	Nasion-basion line: n-ba	5	112	—	—	125	112	—ᴸ	—	108?	98	98–125	111
9	Nasion-opisthion line: n-o	5(1)	149	—	—	171	149	—	141	142	136	136–171	148
10	Horizontal occipital: o-op	6(2)	57	—	—	42	49	—	54	45	56	42–57	50.5
11	Bregma position projected to g-op	bp¹	83	80	66?	77	72.5?	81	68	69	63	63–83	73.2
12	Lambda position projected to g-op	lp¹	189	178	180	188	184?	180	177	171	178	171–189	180.5
13	Bregma position projected to n-o	bp²	59.5	—	—	55	47?	—	38	42	25	25–59.5	44.4
14	Lambda position projected to n-o	lp²	170	—	—	168	156	—	148	147	143	143–170	155.3
15	Inion position projected to n-o	ip	198	—	—	197	180	—	172	173	172	172–198	182
16	Opisthocranion position projected to n-o	op	198	—	—	201	180	—	172	173	170	170–201	182.3
					B. Breadth								
17	Temporo-parietal	8c	137	—	—	—	—	—	132	115	136	115–137	130.0
20	Maximum: eu-eu	8	144.5	147	144?	156	149?	138	145	141	143	138–156	147.9
21	Inner skull width	8.2	136.5	137	—	147	141	—	134.5	130	134	130–147	137.1
22	Least frontal: ft-ft	9	97.5	107	101?	109	102?	100	113	98	99	97.5–113	102.9
24	Greatest frontal: co-co	10	118.5	122	—	122	122?	108?	121	121.5	114	108–122	118.4
26	Biauricular: au-au	11	142	—	124?	132	—	126	—	138	140?	124–142	133.7
27	Biasterionic: ast-ast	12	131	—	121?	130.5	110?	112?	105?	120	122	105–130.5	118.9
33	Distance between temporal lines	ltb	83	—	—	—	—	—	112?	—	104	83–112	99.7

TABLE XXIV (*continued*)

CM	Calvarial Measurements	Symbols and Key Numbers*	Rbo-desian	Nean-derthal	Spy I	La Chapelle-aux-Saints	Gibral-tar	La Quina (adult)	Ehrings-dorf	Tabūn I	Skbūl V	Min.-Max.	Average
						C. Height							
34	Basi-bregmatic	17	129	—	—	131	124?	122?	—	115?	129?	115–131	125.0
35	Opisthion	19	120	—	—	106	115?	—	117	110	134	106–134	117.0
36	Auricular (bregma)	20	107	—	115.5	111	107?	112	121	98	117	98–121	111.0
37	The same above FH	21	105	—	117	110.5	106?	111	121	105	121	105–121	112.0
39	Inner skull	IH	114	—	—	125	111?	—	—	—	120?	111–125	117.5
40	Bregma I	BH	85	79	69	73	69?	64	81	62	80	62–85	73.5
41	Calvarial above g-op	22a	85	80.5	84	80	83?	67	83	70	100	70–100	82.5
44	Bregma II above n-o	bh²	105	—	—	92	96	—	107	86	103	86–107	98.2
45	Vertex above n-o	vh	113	—	—	110	109	—	119	109	125	109–125	114.2
46	Lambda above n-o	lh	86	—	—	91	84	—	80	92	100	80–100	88.8
47	Opisthocranion above n-o	oph	40	—	—	50	59	—	56	60	64	40–64	54.8
48	Inion above n-o	ih	40	—	—	32	28	—	33	38	42	28–42	35.5
						D. Circumferences, arcs and chords							
51	Auriculo-bregmatic arc: po⌢po	24	294	—	300	314.5	—	305	—	—	—	294–314.5	303.4
52	Median sagittal arc I: n⌢o	(25)	310	300	292	294	280?		301	—	310	280–310	298.1
53	Median sagittal arc II: n⌢o	25	372.5	—	—	357	—	—	380	333	373	333–380	363.1
54	Nasion-bregma arc: n⌢b	26	137.5	133	110?	121	124?	120	135	107	118	107–137.5	123.7
56	Nasion-bregma chord: n-b	29	121	116	103?	107	107?	109?	115	96	106	96–116	108.8
58	Bregma-lambda arc: b⌢l	27	117	110	126?	121	—	112	128	117	131	110–131	122.8
59	Bregma-lambda chord: b-l	30	112	104	115?	112	—	107	119	105	107	104–119	110.3
60	Lambda-opisthion arc: l⌢o	28	118	—	—	115	106?	—	117	109?	124	106–124	116.6
61	Lambda-opisthion chord: l-o	31	89	—	—	91	81?	—	87	90?	98	81–98	89.3
						E. Capacity							
74	Cranial capacity (in cc)		1325	1370	—	1610	1300	1350	1450	1270	1510	1270–1610	1400

* Symbols and key numbers to Martin's and other lists.

c. 880 cc.; in any case, close to 900 cc. For the three *Pithecanthropus* skulls this gives an average capacity of 860 cc. with a range from 775 to 900 cc. The capacity of the Ngandong skulls is much greater. Oppenoorth (1937) computed the capacity of Skull I as 1160 cc.; that of Skull V as 1316 cc.; and that of Skull VI as 1160 cc. E. Dubois (1937) found 1143 cc. for Skull I, and 1087 cc. for Skull VI. My calculation of the six skulls is recorded in Table XXII, No. 74; the capacity ranges from 1035 cc. (Skull VI) to 1255 cc. (Skull V) with an average of 1100 cc. The average capacity of the *Homo soloensis* skull is, therefore, only slightly greater than that of *Sinanthropus* but considerably greater than that of *Pithecanthropus*.

2. Length, Breadth, and Height and their Relationships to Each Other

The proportion between breadth and length is the subject of greater attention than any other proportion of the human skull. Since Anders Retzius first recommended the length-breadth index as standard measurement of the skull, it has been looked upon by the great majority of anthropologists all over the world as "the" gauge for determining the authenticity of fossil skulls as well as for discerning definitively the various groups of fossil and modern man.

In recent years the evaluation of the index has advanced—at least in certain quarters—to such an extent that it is regarded as a matchless indicator not only of the characteristic shape of the skull but even of the intelligence and moral qualities of its owner.

In my comparative study of the endocasts of the *Sinanthropus* skulls (1936a) I called attention to the fact that, from the phylogenetic point of view, the length-breadth index is the only one of the three main indices of the endocast that does not tell anything of the evolutionary development of the brain. It remains in principle, unchanged from the anthropoid stage to that of modern man. I wrote in this regard: "In the group of the dolichocranial skulls the aristencephalic Dean Swift ranks with the oligenecephalic *Sinanthropus* II and III and also with the euencephalic Australian and Chinese and the aristencephalic Neanderthal Man of Le Moustier. In the group of the mesocranials the oligenencephalic New Britain, the euencephalic Neanderthalian of Düsseldorf and the Rhodesian man, and the aristencephalic man of La Chapelle-aux-Saints rank with *Pithecanthropus*, *Sinanthropus* I, chimpanzee, and gorilla. In the group of brachycranials chimpanzee, gorilla, and orang-utang rank with the euencephalic Gibraltar man

TABLE XXV

Calvarial Angles (CA) and Indices (CI) of Neanderthalians and Related Forms

CA	Angles	Symbols and Key Numbers*	Rhodesian	Neanderthal	Spy I	La Chapelle-aux-Saints	Gibraltar	La Quina (adult)	Ehringsdorf	Tabūn I	Skhūl V	Min.-Max.	Average
1	Frontal profile	32, a	60°	62°	59°	63°	64°	50°?	73.5°	68°?	68°	50°–73.5°	63°
2	Frontal inclination	32, 1	48°	46°	50°	46°	—	39°	52°	47°	56°	39°–56°	48°
3	Inclination of frontal squama	32.2	45°	44°	47°	43°	—	38°	49°	44°	51°	38°–51°	45°
6	Frontal curvature	—	19°	19°	15°	21°	—	15°	25°	23°	22°	15°–25°	20°
8	Occipital inclination II	33(1b)	68°	69°	67°	64°	64°	59°	63°	74°	71°	59°–74°	67°
10	Occipital curvature	33(4)	99°	—	—	111°	110°	—	107°	120°	115°	99°–120°	110.3°
11	Inclination II	—	60°	—	—	59°	68°	—	70°	78°	63°	59°–78°	66.3°
12	Inclination of whole occipital	—	105°	—	—	88°	97°	—	101°	95°	93°	88°–105°	96.5°
14	Angle of cranial base: ba-n-o	—	7°	—	—	10.5°	5.5°	—	—	5.5°	2°	2°–10.5°	6°
15	Inclination of occipital foramen: n-ba-o	—	153°	—	—	149°	158°	—	—	165°	172°	149°–172°	159°

CI	Indices												
1	Length-breadth	8/1	69.4	73.9	71.3	75.0	76.3	68.2	74.0	77.0	74.5	68.2–76.3	73.3
2	Inner length-breadth	8(2)/4	78.8	78.3	—	79.2	84.0	—	78.7	80.7	80.2	78.3–84.0	79.9
3	Length-basi-bregmatic height	17/1	61.5	—	—	63.0	66.8	60.2	—	63.0	64.7	60.2–66.8	63.2
4	Length-auricular height	21/1	50.0	—	58	53.2	55.2	54.7	61.7	57.4	63.0	50.0–63.0	56.7
5	Length-opisthion height	19/1	57.2	—	—	50.9	59.5	—	59.8	60.2	69.8	50.9–69.8	59.6
6	Breadth height	17/8	89.3	—	—	84.0	83.3	—	—	81.7	90.3	80.5–90.3	85.2
7	Breadth-auricular height	21/8	74.1	—	80.3	71.2	72.5	81.3	83.6	64.5	81.9	64.5–83.6	76.2
8	Bregma height I above g-op	BH/1	40.5	—	34.1	35.1	35.8	31.5	41.3	33.9	41.6	33.9–41.6	36.7
9	Calvarial height above g-op	22a/1	40.5	40.3	41.6	38.5	43.0	33.0	41.1	38.2	52.0	33.0–52.0	40.9
11	Bregma height above n-o	bh²/5(1)	70.4	—	—	53.7	64.4	—	76.0	60.5	75.8	53.7–76.0	66.8
12	Vertex height above n-o	vh/5(1)	75.8	—	—	64.4	73.2	—	84.3	76.7	92.0	64.4–92.0	77.7
13	Lambda height above n-o	lh/5(1)	57.6	—	—	53.2	56.3	—	56.7	64.8	73.6	53.2–73.6	60.4
14	Opisthocranion height above n-o	oph/5(1)	26.9	—	—	29.2	39.8	—	39.7	42.7	47.1	26.9–47.1	37.6
15	Inion height above n-o	ih/5(1)	26.9	—	—	18.7	18.8	—	23.4	26.7	30.9	18.7–30.9	24.2
16	Bregma position above n-o	bp²/5(1)	39.9	—	—	32.2	31.5	—	26.9	29.6	18.7	18.7–39.9	29.8

TABLE XXV (*continued*)

CI	Indices	Symbols and Key Numbers*	Rho-desian	Nean-der-thal	Spy I	La Cha-pelle-aux-Saints	Gibral-tar	La Quina (adult)	Ehrings-dorf	Tabūn I	Skhūl V	Min.-Max.	Aver-age
16a	Vertex position above n-o	vp²/5(1)	74.8	—	—	59.6	67.0	—	58.2	68.8	61.0	58.2–74.8	65.1
17	Lambda position above n-o	lp²/5(1)	114.1			98.3	104.7	—	104.9	103.5	105.1	98.3–114.1	105.1
18	Occipital length I	6(2)/1a	27.5	—	—	20.4	25.8	—	27.8	24.6	29.1	20.4–29.1	25.8
19	Occipital length II	op/5(1)	−33.0	—	—	−17.4	−20.8	—	−21.8	−21.7	−25.0	−17.4–33.0	−23.3
20	Sagittal cranial curvature	5(1)/25	40.1	—	—	48.0	—	—	37.1	42.7	36.5	36.5–48.0	40.9
21	Transverse cranial curvature	11/24	48.3	—	41.3	41.8	—	40.1	—	—	—	40.1–48.3	42.9
23	Transverse fronto-parietal	9/8	67.4	—	72.7	70.0	68.4	72.4	78.0	68.8	69.2	67.4–78.0	70.9
24	Transverse parieto-occipital	12/8	90.6	—	—	83.8	73.8	81.2	72.5	85.2	85.4	72.5–90.6	81.8
26	Lower parietal breadth	8c/11	96.6	—	—	—	—	—	—	83.5	97.3	83.5–97.3	92.5
27	Upper parietal breadth	1tb/11	58.4	—	—	—	—	—	—	—	74.4	58.4–74.4	66.4
28	Fronto-parietal (arc)	27/26	85.2	82.7	114.5	100.0	96.1	93.3	94.8	109.4	96.8	85.2–114.5	97.0
29	Fronto-occipital (arc)	28/26	87.4	—	—	95.3	85.5	—	86.8	101.0	195.0	85.5–105	93.5
30	Parieto-occipital (arc)	28/27	102.5	—	—	95.3	89.2	—	91.5	92.3	108.8	89.2–108.8	96.6
31	Fronto-sagittal (arc)	26/25	36.9	—	—	33.9	35.1	—	35.5	32.4	31.7	31.7–35.5	34.3
32	Parieto-sagittal (arc)	27/25	31.4	—	—	33.9	33.6	—	33.7	35.5	30.6	31.4–35.5	33.2
33	Occipito-sagittal (arc)	28/25	32.2	—	—	32.2	29.9	—	30.8	32.7	33.2	29.9–33.2	31.8
34	Frontal curvature	29/26	88.0	87.3	93.7	88.5	86.3	90.8	85.4	89.7	90.0	85.4–93.7	88.8
35	Flatness of the frontal bone (subtense, st, to n-b: n-b)	st/29	18.4	18.2	14.5	19.2	19.7	13.8	22.2	20.3	19.8	13.8–22.2	18.5
39	Parietal curvature	30/27	96.0	94.7	91.2	92.5	94.3		93.2	89.8	94.0	89.8–96.0	93.2
40	Occipital curvature	31/28	74.1	—	—	79.2	76.5	—	74.3	83.3	79.0	74.1–83.3	77.7
43	Nasion-basion length	5/5(1)	75.2	—	—	73.1	75.2	—	—	76.2	72.0	72.0–76.2	74.3

* Symbols and key numbers to Martin's and other lists.

and the aristencephalic recent inhabitants of Lower Austria. The dolichocephalic Dean Swift stands side-by-side with *Sinanthropus*, and the ultrabrachycephalic Austrian of today with the orang-utang."

What is true of the endocast is true of the calvaria itself. The length-breadth index of the *Sinanthropus* skull varies only little (71.4–72.6) with an average of 72.2 when the average maximum breadth (CM No. 20) is taken as greatest breadth. The skull is, therefore, dolichocranial. It shares this characteristic with the Ngandong skull, the average of which is also 72.0, although here the variation is much greater ranging from 66.2 (Skull V) to 76.7 (Skull IX); that is to say, the Ngandong skulls include hyperdolichocranial ones as well as mesocranial ones. In the anthropoids the range is considerably wider; in the male gorilla, for example, individuals occur with an index of 70.4 and others with one of 94.2; and in the male orang-utang with indices of 71.8 and 96.3. This great variability in the great apes depends mainly upon the varying development of the superstructures, that is, the suprafacials and the nuchal crest, and has, therefore, little bearing on the form of the braincase proper. But even if the superstructures are disregarded dolichocranial, mesocranial, and brachycranial skulls are a common occurrence in the great apes, in particular in the gorilla (cf. Harris, 1926). However, the three anthropoids, as a whole, incline to brachycephaly, in contrast to the primitive hominids which tend to dolichocephaly. In modern man, as is well known, all these incidences are represented despite the fact that the superstructures have almost completely disappeared. The variability of the index ranges from 65.2 to 89.3, if the most extreme cases are left out of account. On the other hand, it is interesting to note that *Pithecanthropus* Skull I has an index of 71.2, if the estimate of breadth

TABLE XXVI

Minimum-Maximum Values and Averages of Linear Calvarial Measurements (CM) of All Hominid Groups and Anthropoids

CM	Calvarial Measurement	Minimum-Maximum Values					Averages					
		Anthrop.	Sinanthropus	Homo soloensis	Neander-thalians	Modern Man	Anthrop.	Pith. II	Sinanthropus	Homo soloensis	Neander-thalians	Modern Man
	A. Length											
1	Maximum: g-op	—	188–199	193–219.5	183–210	158–203	—	176.5	193.6	209	198.4	185.6
2	Horizontal projective	—	184–197.5	193–215	183–207	156–201	—	174?	191.4	197.7	194.4	184.3
4	Nasion-opisthocranion: n-op	—	185–194	190–212	180–207	155–195	—	—	189	198.7	193.9	180.3
5	Glabella-lambda line: g-l	—	169–183	174–198	174–196	154–194	—	159?	176.8	182.8	184.7	181.3
6	Nasion-lambda line: n-l	—	166–180	178–195	170–192	154–189	—	148	175	183.6	181.8	178.0
7	Inner skull	—	156–173	153–172	161–186	—	—	—	166	161	171.6	—
8	Nasion-basion line: n-ba	110–139	rec. 105.5	113–114	98–125	90–107	—	—	(105.5)	113.5	111	102.7
9	Nasion-opisthion line: n-o	—	144–147	142–162	136–171	122–146	127(W)*	134?	145.3	153.4	148	135.0
10	Horizontal occipital: o-op	11–28	47–50	46–60	42–57	42–69	17(W)	42	48.3	50.7	50.5	56.0
11	Bregma position projected to g-op	—	74–81	68–84.5	63–83	57–84	—	64?	77.3	77.7	73.2	71.6
12	Lambda position projected to g-op	—	165–181	166–192	171–189	149–194	—	153	172	176.6	180.5	179.5
13	Bregma position projected to n-o	40–58	52–62	56.5–67.0	25–59.5	18–44	47.2(W)	44	56.7	61.4	44.4	33.2
14	Lambda position projected to n-o	101–131	142.5–154	153–170.5	143–170	126–166	116.6(W)	134	148.2	162	155.3	148.7
15	Inion position projected to n-o	—	} 178–182	} 187–206	172–198	147–187	} —	} 164.5	} 180.3	} 195.4	182.0	169.5
16	Opisthocranion position projected to n-o	—			170–201	146–184					182.3	165.6
	B. Breadth											
17	Temporo-parietal	93–104	133–139	140–152	—	122–156	99.1(W)	131	136.2	146	—	131.5
20	"Maximum"	—	137–143	138–156	138–156	124–157	—	135	141.0	146	147.9	133.6
21	Inner skull	—	122–129	129–138	130–147	—	—	121	124.2	135	137.1	—
22	Least frontal	—	81.5–91	—	97.5–113	—	—	79	87.2	—	102.9	—
26	Biauricular	104–148	141–151	133–163	124–142	115–132	119.6(W)	129?	145.5	148	133.7	121
27	Biasterionic	—	103–117	—	105–130.5	102–115	—	120?	111.8	—	118.9	108.6
33	Distance between temporal lines	—	86–104	106–119	—	77–135	—	67	93.5	112.8	—	98.6

TABLE XXVI (*continued*)

CM	Calvarial Measurement	Minimum-Maximum Values					Averages					
		Anthrop.	Sinanthropus	Homo soloensis	Neander-thalians	Modern Man	Anthrop.	Pith. II	Sinan-thropus	Homo soloensis	Neander-thalians	Modern Man
	C. Height											
34	Basi-bregmatic	85–100(W)	rec. 115	118–131	115–131	123–141	—	105?	(115)	122.5	125	134
35	Opisthion	—	103–106.5	91–112	106–134	126–144	—	92	104.6	105	117	136.1
36	Auricular	—	95–105	105–111	98–121	104–121	—	89	98.4	107.4	111.5	113.5
39	Inner skull	—	—	—	111–125	—	—	—	—	—	117.5	—
40	Bregma I	—	66–80	73–82	62–85	74–92	—	60.5	72.9	76.7	73.5	82.7
41	Calvarial	—	67–82	77.5–84	70–100	80–98	—	66	74.6	78.8	82.5	87.4
44	Bregma II above *n-o*	—	89–95	95–102.5	86–107	95–114	—	78	91.3	98.7	98.2	107.7
45	Vertex above *n-o*	—	100–103	102–113.5	109–125	112–133	—	88	101.3	105.7	114.2	124.6
46	Lambda above *n-o*	—	81–83	77–93.5	80–100	85–102	—	74.5	82.3	84.1	88.8	94.6
47	Opisthocranion above *n-o*	—	41–53 }	31–50	40–64	43–82	—	37	47 }	36.3 }	54.8	67.0
48	Inion above *n-o*	—	}	}	28–42	25–45	—	37	}	}	35.5	36.8
	D. Circumferences, arcs and chords											
50	Max. horizontal circumf.	306–595	557–582	—	—	440–599	391(M)	—	564	—	—	507
51	Transverse cranial arc	179–235	277–310	275–305	294–314.5	286–344	200(M)	262	286.7	287.2	303.4	311
52	Mid-sagittal arc: *n⌢op*	—	263–293	287–309	280–310	261–315	—	234?	276	293.8	298.1	290.5
53	Total mid-sagittal arc: *n⌢o*	178–285	321–337	338–381	333–380	343–398	221.3(M)	302?	330	355	363.1	372.2
54	Frontal arc (*n⌢b*)	70–92	115–129	122–139	107–137.5	111–139	77(M)	107?	120.3	130.8	123.7	128.0
56	Frontal chord: *n-b*	—	102–115	112–120.5	96–116	99–117	—	90?	109.8	116.7	108.8	112.1
58	Parietal arc: *b⌢l*	60–71	92–113	102–117	110–131	116–142	64.2(M)	94	102.5	107.4	122.8	130.4
59	Parietal chord: *b-l*	—	86–106	97–111	104–119	100–127	—	91	96.2	102	110.3	116.5
60	Occipital arc: *l⌢o*	53–74	106–118	109–128	106–124	103–123	61.2(M)	101	114	116.8	116.6	114.0
61	Occipital chord: *l-o*	—	80–86	78–106	81–98	85–97	—	75	84	88.2	89.3	92.8
	E. Capacity											
74	Cranial capacity (in cc.)	300–585	915–1225	1035–1255	1220–1610	1125–1540	415(M)	775 (860 av.)	1043	1100	1400	1300

* M, R. Martin.   W, Weidenreich.

TABLE XXVII

Minimum-Maximum Values and Averages of Calvarial Angles (CA) and Indices (CI) of All Hominid Groups and Anthropoids

CA	Angles	Minimum-Maximum Values					Averages					
		Anthrop.	Sinanthropus	Homo soloensis	Neanderthalians	Modern Man	Anthrop.	Pithecanthropus II	Sinanthropus	Homo soloensis	Neanderthalians	Modern Man
1	Frontal profile	—	56°–63°	54°–66°	50°–73.5°	72°–96°	—	52°	60.5°	62°	63°	83.2°
2	Frontal inclination I	—	42°–46.5°	46°–55°	39°–56°	45°–59°	—	41°	44.3°	48.7°	48°	50.8°
3	Inclination of frontal squama to g-op line	max. 39.5	38°–45°	41°–54°	38°–51°	42°–57°	max. 39.5	40°	42.5°	45.8°	45°	49.2°
6	Frontal curvature	—	16°–24°	18°–23°	15°–25°	21°–31°	—	—	20.2°	20.5°	20°	26.8°
8	Occipital inclination II	—	57°–68°	59°–73°	59°–74°	67°–80°	—	62°	62.7°	62.8°	67°	75.9°
10	Occipital curvature	—	98°–106°	91°–102°	99°–120°	111°–132°	—	103°	103.2°	98.2°	110.3°	122.6°
11	Frontal inclination II	48°–58°(W)	57°–59°	56°–59°	59°–78°	68°–79°	52.5°(W)	60°	58°	57.6°	66.3°	72.6°
12	Inclination of the whole occipital	80.4°–85.5°(W)	88°–99°	89°–108°	88°–105°	92°–116°	83.1°(W)	90°	93.1°	98°	96.5°	99°
14	Angle of cranial base: ba-n-o	8°–15°	rec. 6°	7°	2°–10.5°	2°–11°	10°	5°	rec. 6°	7°	6°	6°
15	Inclination of the occipital foramen: n-ba-o	121°–134°	rec. 155°	154°–155°	149°–172°	145°–171°	127°	162°	rec. 155°	154.7°	159°	156°

CI	Indices	Minimum-Maximum Values					Averages					
		Anthrop.	Sinanthropus	Homo soloensis	Neanderthalians	Modern Man	Anthrop.	Pithecanthropus II	Sinanthropus	Homo soloensis	Neanderthalians	Modern Man
1	Length-breadth	70.4–96.3(M)	71.4–72.6	66.2–76.7	68.2–76.3	65.2–89.3	84.3(M)	76.5	72.2	72.0	73.3	72.8
2	Inner length-breadth	—	74.1–78.2	78.6–86.7	78.3–84.0	—	—	81.7	76.3	83.7	79.9	—
3	Length-height	63.5–100.4(M)	rec. 59.4	59.8–63.8	60.2–66.8	65.6–77.9	74.3(M)	59.6	rec. 59.4	60.2	63.2	72.9
4	Length-auricular height	—	48.7–52.8	49.8–54.8	50.0–63.0	54.8–71.5	—	52.2	50.9	53.0	56.7	61.7
5	Length-opisthion height	—	52.7–56.0	44.3–56.3	50.9–69.8	70.7–81.7	—	52.1	54.1	51.8	59.6	73.6
6	Breadth-height	75.0–112.3	rec. 75.6	77.2–90.4	80.5–90.3	86.7–109.2	88.3(M)	rec. 77.8	rec. 75.6	84.2	85.2	100.6
7	Breadth-auricular height	—	62.2–74.0	72.6–78.4	64.5–83.6	75.6–93.2	—	68.1	70.3	74.9	76.2	85.3
8	Bregma height I	—	34.4–40.2	34.9–41.7	33.9–41.6	41.6–53.7	—	34.2	37.6	37.8	36.7	45.2
9	Calvarial height to g-op line	13.8–43.7	34.8–41.2	36.8–42.6	33.0–52.0	41.4–57.0	27.9(M)	35.3	38.5	39.5	40.9	47.5
11	Bregma height II	41.4–50.8	61.8–64.6	60.5–70.3	58.7–76.0	68.3–87.0	46.1(W)	58.2	62.7	64.4	66.8	78.5
12	Vertex height	50.6–56.2	67.7–71.6	65.5–74.6	64.4–92.0	84.3–98.4	54.0(W)	64.2	69.4	69.0	77.7	91.0

TABLE XXVII (continued)

CI	Indices	Minimum-Maximum Values					Averages					
		Anthrop.	Sinanthropus	Homo soloensis	Neander-thalians	Modern Man	Anthrop.	Pithe-canthro-pus II	Sinan-thropus	Homo soloensis	Nean-dertha-lians	Modern Man
13	Lambda height	43.3–45.7	55.6–57.6	50.0–57.7	53.2–73.6	61.1–80.5	44.7(W)	55.6	56.6	54.7	60.4	69.1
14	Opisthocranion height	19.5–25.6	27.6–32.7	21.8–30.9	26.9–47.1	30.7–61.6	22.2(W)	27.6	32.3	24.1	37.6	49.6
15	Inion height				18.7–30.9	18.9–36.9	42.0				24.2	27.3
16	Bregma position above n-o	30.0–38.1	36.1–42.2	36.0–46.5	18.7–39.9	22.3–27.3	35.3(W)	32.9	38.9	40.2	29.8	24.2
16a	Vertex position above n-o	58.8–68.3	64.5–67.7	53.2–75.5	58.2–74.8	58.2–70.8	64.1(W)	66.0	66.3	64.6	65.1	65.4
17	Lambda position above n-o	93.7–95.6	98.3–104.8	97.5–116.6	98.3–114.1	103.3–117.8	95.3(W)	100.0	102.0	105.7	105.1	109.3
18	Occipital length I	10.0–14.1	25.2–26.1	23.8–28.0	20.4–29.1	25.1–36.9	12.7(W)	24.1	25.7	25.5	25.8	30.6
19	Occipital length II above n-o	-5.9–7.2	-23.0–24.8	-24.5–33.0	-17.4–33	-18.0–29.8	-6.4(W)	-22.5	-24.0	-28.7	-23.3	-21.8
20	Sagittal curvature above n-o	45.4–57.6	43.6–44.8	35.4–45.4	36.5–48.0	35.2–39.9	54.7(W)	44.4	44.0	42.3	40.9	36.6
21	Transverse cranial curvature	—	47.1–54.8	47.5–57.2	40.1–48.3	36.2–41.2	—	45.6	50.8	51.6	42.9	38.6
23	Transverse fronto-parietal	50.0–76.4	59.7–64.1	Skull V 70.4	67.4–78.0	65.0–76.6	66.3(M)	58.5	61.7	Sk. V: 70.4	70.9	71.6
24	Transverse parieto-occipital	—	78.3–86.2	Skull V 77.3	72.5–90.6	76.6–85.6	83.8(M)	89.0	81.7	Sk. V: 77.3	81.8	82.4
26	Lower parietal breadth	71.0–94.6 (♂ + ♀)	92.2–94.4	89.1–106.8	85.3–97.3	103.2–118	85.1(W) Gor. ♂: 68.4	101.5	94.5	97.8	92.5	107.9
27	Upper parietal breadth	♀5.7–36.8	60.2–68.9	65.2–88.0	58.4–74.4	64.5–104.1	♀15.0(W)	51.8	64.2	76.9	66.4	81.2
28	Fronto-parietal (arc)	77.4–85.9	75.4–91.3	76.3–87.8	85.2–114.5	92.2–116.3	82.7(M)	(87.8)	83.9	82.5	97.0	102.2
29	Fronto-occipital (arc)	—	95.3–96.0	79.8–100.0	85.5–105.0	84.1–93.6	79.4(M)	—	95.7	89.6	93.5	89.2
30	Parieto-occipital (arc)	—	108–124	102.0–119.6	89.2–108.8	80.0–93.7	95.3(M)	105.3	119.7	109.5	96.6	87.6
31	Fronto-sagittal (arc)	—	34.7–36.8	35.5–39.3	31.7–35.5	33.1–36.4	34.9(M)	35.5	36.5	36.9	34.3	34.6
32	Parieto-sagittal (arc)	—	27.6–30.7	29.6–31.4	31.4–35.5	33.7–38.7	29.0(M)	31.1	28.8	30.3	33.2	35.4
33	Occipito-sagittal (arc)	—	33.1–35.2	31.3–35.5	29.9–33.2	30.0–32.0	27.0(M)	33.4	34.5	32.8	31.8	31.1
34	Frontal curvature	77.8–93.5	86.9–91.8	86.8–91.8	85.4–93.7	84.2–95.8	87.4(W)	—	89.9	89.5	88.8	85.7
35	Flatness of frontal bone	—	14.8–18.6	15.2–19.9	13.8–22.2	19.3–26.8	—	—	16.4	17.4	18.5	22.9
39	Parietal curvature	93.2–97.0	93.1–95.7	94.2–97.3	89.8–96.0	86.3–92.5	95.3(W)	95.9	94.1	95.7	93.2	89.4
40	Occipital curvature	80.8–95.3	72.8–74.5	68.4–87.0	74.1–83.3	75.8–84.7	89.4(W)	75.0	73.8	75.7	77.7	80.8
43	Nasion-basion length	79.0–91.3	—	—	—	—	83.8	—	72.6	74.1	75.0	75.3

* M, R. Martin.   W, Weidenreich.

is accurate, and Skull II an index of 76.5.   This shows a greater variability than is the case in *Sinanthropus*.   I should, therefore, not be greatly surprised if we should some day find a fossil hominid with a brachycranial skull.

The inner length-breadth index of *Sinanthropus* ranges from 74.1 to 78.2 with an average of 76.3; in the Ngandong skulls the corresponding figures are 78.6 to 86.7 with an average of 83.7; in *Pithecanthropus* Skull I the index totals 82.3; and in Skull II 81.7.   In all these cases, the inner breadth is greater in proportion to the length than is the case with the external measurements.   The same is true of modern man.   This difference is the result, of course, of the greater thickness of the walls on both ends of the glabella-opisthocranion line, than that of the euryon region.   The inner length-breadth index represents, therefore, the real proportions of the brain. It shows that, as early as in primitive man, there is a clear tendency to brachycephalic forms; this demonstrates still more impressively than the external index the stupidity of man like the French sociologist Vacher de Lapouge (1899), the German anthropologist Roese (1906) and their modern scientific and lay parrots who consider people with smaller external length-breadth indices mentally superior to those with larger ones even if they belong to the same population.

In contrast to the length-breadth index, the length-height index and, to a smaller extent, the breadth-height index are of the utmost significance in the phylogenetic evolution of the human skull.   When Schwalbe made his pioneer anthropometric examination of the Trinil and Neanderthal skulls (1901, 1902) he was eager to establish a convenient basal line representing the greatest length of the cap, and a vertical one corresponding to the greatest height.   This basal line, which cannot be replaced by any other where defective skull caps are concerned, is the glabella-inion line or, more correctly, the glabella-opisthocranion line; for inion and opisthocranion coincide in primitive hominid skulls, as has been mentioned above.   The greatest height—calvarial height—is represented by the vertical drawn from the vertex of the vault, regardless of its position, to the basal line.

The calvarial height in *Sinanthropus* is 74.6 mm. ranging from 67 to 82 mm., and the calvarial height index is 38.5, ranging from 34.8 to 41.2.   This index is far below the index of modern man with an average of 47.5 and a range from 41.4 to 57.0.   The corresponding index totals in *Pithecanthropus* Skull I 34.3 and in Skull II 35.3 with an average of 34.8.   The *Pithecanthropus* skull is, therefore, nearly 4 index-units lower than the *Sinanthropus* skull.   On the other hand, the Ngandong skull with an average of 39.5 and a range from 36.8 to 42.6 exceeds the *Sinanthropus* skull by one index unit.

It is not my intention to discuss here all the different heights of the *Sinanthropus* vault as expressed by the height or the length-height indices of its main landmarks (bregma, vertex, lambda) and the position of their foot-points, which can be calculated on the basis of the glabella-opisthocranion line or any substitute line.   The reader who is interested in these figures is referred to Tables XIX–XXII and Tables XXVI and XXVII which contain the corresponding figures for the other hominid groups.

As I have already shown in the prolegomena to this chapter, the best possible method for providing a really comprehensive picture of the length-height proportions of the calvaria is that of relating all height measurements to the nasion-opisthion line as a base.   In a median sagittal craniogram (cf. Figs. 180–184), the heights of bregma, vertex (that is, the highest point of the curve above this base) and lambda indicate not only the height of the vault in its different sections but also the elevations of the frontal and occipital bones above the base.   If the nasion-bregma line (n-b) and the opisthion-lambda line (o-l) are drawn as auxiliary lines, the angles

they form with the base-line (nos. 11 and 12) disclose (cf. Fig. 181; Table XX) the degree to which the two bones have risen. In order to distinguish these angles from those related to other basal lines I have called them "frontal inclination angle II" and "inclination angle of the whole occipital bone." The craniogram affords still further possibilities: in the same way the height of the opisthocranion and the height of the inion above the base-line can be determined (cf. Fig. 184). If the verticals drawn from these landmarks fall beyond the opisthion the base-line has to be prolonged backward, correspondingly. The distance of the foot-points of the verticals from the opisthion indicate the degree to which the calvaria bulges backwards and, thereby, the position of the occipital foramen in relation to the length of the skull. The measurement of this distance, therefore, supplements the so-called "horizontal occipital length" by correlating it with the calvaria itself, instead of with the Frankfort Horizontal, as the prescribed measurement does.

The nasion-opisthion line is, of course, shorter than the maximum length. It varies very little in *Sinanthropus* ranging from 144–147 mm. with an average of 145.3 mm. In *Pithecanthropus* Skull II it measures only about 134 mm. in accordance with the smallness of the whole skull. At first glance I was struck by the fact (which, so far as I know, has not been recognized before) that this distance is much smaller in modern man. None of the skulls I have measured— not even the longest of them—equals *Sinanthropus* Skull XII in this respect although *Sinanthropus* Skull V certainly exceeded even Skull XII in length. The average, in modern man, is only 135 mm. with a range of 122–146 mm. The reason for this difference will be discussed later on. The Ngandong skull, and partly also the Neanderthalians, surpass even *Sinanthropus* with averages of 153.4 and 148 mm., respectively.

The nasion-opisthion line measures only three-quarters of the maximum length of the skull as in *Sinanthropus* (index 74.8) and in the Neanderthalians (index 74.6), but this ratio is distinctly smaller in modern man (index 72.6) and in the Ngandong skull (index 73.3). Only *Pithecanthropus* surpasses all other groups (index 75.9). The anthropoids, on the other hand, have a much higher index than the hominids; it amounts to nearly 95 in female individuals, and to over 80 in the male gorilla when the inion (that is, the entire height of the nuchal crest) and not the opisthocranion is taken as posterior landmark of the maximum length.

The length-height indices of bregma, vertex and lambda with the nasion-opisthion as base (nos. 11–13) amount in *Sinanthropus* to 62.7, 69.4 and 56.6 ranging from 61.8 to 64.6 for the bregma, from 67.7 to 71.6 for the vertex, and from 55.6 to 57.6 for the lambda. The corresponding indices in modern man (cf. Fig. 185) are much higher their averages totalling 78.5, 91.0, and 69.1. These are 16 units more for the bregma, 22 more for the vertex, and 13 more for the lambda. *Pithecanthropus* Skull II (cf. Fig. 186) shows lower indices than *Sinanthropus* even if not the averages but the individual *Sinanthropus* skulls are taken into account. The averages of *Pithecanthropus* are 58.2, 64.2, and 55.6, or 4, 5, and 1 units less than *Sinanthropus*. Each of the three average indices of the Ngandong skulls (cf. Fig. 187) is different: The bregma index is higher than in *Sinanthropus* and *Pithecanthropus*, the vertex index is about the same as in *Sinanthropus* while the lambda index is lower than in the other two groups. In the anthropoids (cf. Figs. 188–190; and Table XXVII) all the indices are considerably lower and even their maximum values fall far behind the minimum values of many hominid groups. In all the groups from anthropoids to modern man the bregma is higher than the lambda; the difference amounts to only 2.6 per cent of the entire height of the vault in the anthropoids, increases to 4 per cent in *Pithecanthropus*, to 8.8 per cent in *Sinanthropus*, and reaches 10.3 per cent in modern man.

In other words, the bregma region rises to a relatively higher level than does the lambda region.

The opisthocranion and inion coincide in *Sinanthropus*, as has been mentioned above. Their length-height index above the nasion-opisthion base amounts to 32.2. In *Pithecanthropus* and the Ngandong skulls where the two landmarks also occupy the same place the index totals 27.6 and 24.1. In modern man, however, their locations are different: the opisthocranion with an index of 49.6 seemingly has shifted upward while the inion, with an index of 27.3, has apparently kept its place. Yet, when the heights of the opisthocranion and the inion in proportion to that of the vertex are computed it becomes evident that both landmarks have actually changed their locations and that the inion, in contrast to the opisthocranion, has moved downward. Table XXVIII shows the amplitude of this movement. In the anthropoids the inion with an index of 27.8 is high and very close to the lambda while the opisthocranion is on a much lower level. In modern man the conditions are exactly reversed: the opisthocranion with an index of 54.5

TABLE XXVIII

Upward Shift of Opisthocranion and Downward Shift of Inion

	Anthropoids (Average)	Pithecanthropus II	Sinanthropus (Average)	Homo soloensis (Average)	Neanderthalians (Average)	Modern Man (Average)
Vertex-height index	34.0	64.2	69.4	69.0	77.7	91.0
Opisthocranion-height index	22.2	27.6	32.3	24.1	37.6	49.6
Inion height index	42.0	27.6	32.3	24.1	24.2	27.3
Opisthocranion height index in proportion to vertex height index	41.1	42.9	46.2	34.8	48.4	54.5
Inion height index in proportion to vertex height index	77.8	42.9	46.2	34.8	31.1	29.9

is high, and the inion with an index of 29.9 has moved down. *Sinanthropus* occupies a median position in this respect; the opisthocranion has moved upward and the inion downward when compared with the anthropoids. *Pithecanthropus* comes closer to the anthropoids with regard to the opisthocranion but closer to man with regard to the inion. The Ngandong skulls have the same peculiarity, the only difference being that, in both cases, the tendency is still more pronounced than in *Pithecanthropus* and *Sinanthropus*. The opisthocranion is on an even lower level, relatively, than in the great apes while the inion is on a higher level. The changes on the outer relief of the occiput have no connection whatever with those on the inner side. The internal protuberance that marks the boundary between cerebellum and cerebrum is, in *Sinanthropus*, close to the opisthion and far below the inion, as Table VIII shows, whereas in modern man it is situated on the same level as the inion but below the opisthocranion. It is true that this altered orientation is partly due to the downward movement of the inion but, more essentially, it is due to an increase in the height of the cerebellum that pushes the internal protuberance upward.

The increase in the height of the vault indicated by the increase of the bregma, vertex, and lambda height indices, when *Sinanthropus* is compared with modern man, also becomes evident when the angles that the nasion-bregma and the opisthion-lambda lines form with the base-line are measured. These measurements show the extent to which the frontal and occipital bones

have turned about a transverse axis laid through nasion and opisthion. The frontal inclination angle II (no. 11 of the lists) has an average measurement of 58.2° with the very small range of 1° more or less in the four measurable *Sinanthropus* skulls whereas it totals 72.6° with a range from 68° to 79° in modern man. This is an average increase of more than 14°. In *Pithecanthropus* II the angle is a little higher (60°), and in the Ngandong skulls about the same (57.6°) as in *Sinanthropus*. In the anthropoids the angle is distinctly lower than in *Sinanthropus* measuring 52.5°. However, it is noteworthy that this is only 6° smaller than in *Sinanthropus* while the difference between *Sinanthropus* and modern man is more than double. The occipital bone is quite different. The average of its inclination angle (no. 12) is 93° in *Sinanthropus*, 90° in *Pithecanthropus*, and 98° in the Ngandong skulls with the individual variation rising to 108° in the Ngandong skulls. In modern man, the average is 99° with a range from 92° to 116°. It can be gathered from these figures that the rising of the occiput by a rotation of the entire bone about a transverse axis through the opisthion is much less pronounced than it is in the case of the frontal bone and, furthermore, that there is great variability in modern man, quite independent of the special form of the occipital bone itself. I shall return to this question later.

Another way to estimate the degree of erection of the two cranial bones is to determine the distances of the foot-points of the bregma and inion from the nasion, as starting point of the base-line, expressed in proportion to the length of the base-line. Schwalbe introduced this measurement for the glabella-inion line, but only with regard to the bregma. But the same principle can be applied to the nasion-inion line and to the lambda. The bregma position index (no. I 16) is 38.9 with a range from 36.1 to 42.2 in *Sinanthropus*; in modern man, however, it is 24.2, with a range from 22.3 to 27.3. This means that, in the former, the foot-point of the bregma lies much farther toward the back. The Ngandong skulls with an average of 40.2 come very close to *Sinanthropus*. In *Pithecanthropus* II the index totals only 32.9, apparently because of the shorter sagittal length of the frontal bone in proportion to the median sagittal arc; the fronto-sagittal arc index (no. I 31) amounts to only 35.5 in the *Pithecanthropus* skull as against 36.5 in *Sinanthropus* (or 34.6 in modern man). It is surprising that in the anthropoids the bregma position index with an average of 35.3 should be smaller than in *Sinanthropus*, *Pithecanthropus* and the Ngandong skulls. This seeming divergency is due to the method applied in determining the average; I computed first the average of each of the three genera of this group, and then that of the three averages. In most cases the method of computation makes no essential difference but in this instance it does. The averages of the bregma position index of gorilla and chimpanzee amount to 37.7 and 38.1, figures which fit fairly well into the general scheme; but the orang-utang has an average index of only 30.0, and female individuals even fall within the range of modern man, obviously as a result of the high-vaulted frontale of the orang-utang calvaria and the almost complete absence of suprafacials.

The differences in the lambda position of *Sinanthropus* and modern man are much smaller than those of the bregma. But there is still another feature that should be noted. The average of the inclination angle of the occipital bone (no. A 12), is greater than 90° in all the groups examined. This means, as a glance at the craniograms (Figs. 182, 184, 185, 187) will show, that the lambda foot-point falls beyond the opisthion. In the great apes, however, the angle is smaller than 90°; and the foot-point lies within the base-line, as it does in all anthropoids in which the average of the angle amounts to 83.1° (cf. Figs. 188–190). This is the case also in *Sinanthropus* Skull XI (88°), in Ngandong Skull XI (89°), but never in modern man, at least so far as my experience goes. If the foot-point falls beyond the opisthion the index, of course,

becomes greater than 100.   The average of the lambda position is 102 in *Sinanthropus*, 100 in *Pithecanthropus*, 105.7 in the Ngandong skull, and 109.3 in modern man.

The breadth-height index, with the basion-bregma line representing the height, is 75.6 in *Sinanthropus* as compared with 95.0 in modern man.   In *Pithecanthropus* II the index is 77.8, and in the Ngandong skulls 84.2.   Most students do not realize that in female anthropoids or in male individuals in which the height of the sagittal crest can be eliminated this index is higher than in primitive hominids and reaches even to within the variation range of modern man; the average index of the anthropoids is 88.3 (according to Martin) with an individual range of 75.0 to 112.3 while the corresponding figures for modern man are 95 and 85.5 to 106.0.   It must be borne in mind, however, that neither in *Sinanthropus* nor in *Pithecanthropus* has the basion been preserved and that, therefore, the basion-bregma height is merely estimated.   For this reason, the results are more reliable when we substitute the auricular height for the basion-bregma height.   The average of this breadth-height index (no. I 7, Table XXVII) in *Sinanthropus* amounts to 70.3 the individual measurements ranging from 62.2 to 74.0, and that of modern man to 85.3 ranging from 75.6 to 93.2.   The corresponding figure for *Pithecanthropus* II is 68.1, and for the Ngandong skulls the figures are 74.9 and 72.6 to 78.4.

In contrast to the length-breadth index, the breadth-height index like the length-height index expresses the lowness of the *Sinanthropus* calvaria as compared with modern man and indicates the change in height in the course of evolution.   However, as has already been shown, the interporial and coronal craniograms (Figs. 191–200) demonstrate that the breadth of the calvaria differs significantly at different levels from the base to the top.   These differences can be illustrated in figures, by computing the breadth-height index for each level concerned, as shown in Table XXIX.

TABLE XXIX

Breadth-Height Indices in the Interporial Coronal Plane at Different Levels

	Porion Level	Auriculare Level	Level of the Temporo-Parietal Suture
Sinanthropus (average)	81.2	68.4	73.0
Sinanthropus Skull III	77.8	68.4	72.6
Pithecanthropus Skull II	71.8	66.6	65.2
Pithecanthropus Skull IV	75.3	59.5	73.5
Homo soloensis Skull VI	80.8	71.4	72.2
Homo soloensis Skull IX	90.0	76.8	79.6
Rhodesian Skull	85.8	75.7	76.2
Modern Man, male (hyperdolichocranial Australian)	105.0	101.3	96.3
Modern Man, female (hyperbrachycranial Austrian)	97.5	90.0	76.3
Gorilla, female	60.7	58.2	67.3

From these figures it can be gathered that, except in gorilla, the index is highest in all the hominids at the porion level.   But the index at the auriculare level is lower than that at the level of the temporoparietal suture in the *Sinanthropus* skulls, the Ngandong skulls, the Rhodesian skull, and the gorilla while, conversely, the latter is higher than the former in modern man, and more pronounced in the brachycranial than in the dolichocranial types.   In *Pithecanthropus* Skull II there is a slight difference in favor of the biauricular breadth index, but in *Pithecanthropus* Skull IV (cf. Fig. 196) the temporoparietal breadth index exceeds the biauricular breadth index to the same extent as in gorilla.   In other words, in all cases in which the temporoparietal

breadth index exceeds the biauricular index, the temporoparietal breadth is the smaller of the two, and vice versa. These differences can also be illustrated by the lower parietal breadth index (no. I 26, Table XXVII) which expresses the temporoparietal breadth in proportion to the biauricular breadth. When the biauricular breadth is greater than the temporoparietal the index is below 100, but when the reverse conditions exist it is above 100. In *Sinanthropus* the average index is 94.5 with a range from 92.2 to 94.4 while in modern man the index is 107.9 ranging from 103.2 to 118; in no case less than 100. The Ngandong skulls vary around the 100 mark with five skulls below and one above (average index 97.8). *Pithecanthropus* Skull II is a little above the mark (101.5) while the male skull IV has an index of 81.2 which falls within the range of the anthropoids (71.0–94.6 for chimpanzee, female orang-utang and gorilla).

The transverse frontoparietal index of *Sinanthropus* with an average of 61.7 shows that the frontal squama is distinctly narrower than that of modern man (index 71.6) while *Pithecanthropus* II exceeds even *Sinanthropus* in this respect (index 58.5). On the other hand, the transverse parieto-occipital index of *Sinanthropus* (81.7) falls entirely within the range of modern man (76.6–85.6). This is not surprising since the index in question is merely an expression of the well-known fact that the oval form of the vault is, in principle, common to anthropoids and to all the types of hominids. Nevertheless, there are certain differences in the special form of ovalness which have been used by G. Sergi as schemes for classifying human skulls. As has been shown above, the *Sinanthropus* skulls conforms in most cases to the "Ellipsoides" type because of the slight elongation of its occiput. *Pithecanthropus* Skull II with a transverse parieto-occipital index of 89.0 possesses a more rounded and broader occiput that corresponds to Sergi's "Sphenoides" type. Both *Pithecanthropus* Skulls I and IV exhibit the same peculiarity. This is one of the characteristic features in which the two prehominids differ from each other. The anthropoids with an average index of over 85 fall in the same category as *Pithecanthropus;* belong to the "Sphenoides" type.

3. The Curvature of the Vault and the Part Played by the Individual Cranial Bones.

The heights of the landmarks—bregma, vertex, lambda and opisthocranion—above the nasion-opisthion base-line give only a general idea of the expansion of the vault since they do not take into account the extent of the individual cranial bones. More accurate measurements can be obtained by considering the cranial curvature indices (nos. I 20 and 21) and the curvature indices of the individual bones (nos. I 28–40).

The sagittal cranial curvature index is 44.0 in *Sinanthropus* and 36.6 in modern man. In *Pithecanthropus* II the index is about the same as in *Sinanthropus* (44.4) while in the Ngandong skulls it is a little smaller (42.3). The transverse cranial curvature index is 50.8 in *Sinanthropus* and 38.6 in modern man. In *Pithecanthropus* II it is less (45.6) but in the Ngandong skulls it is greater (51.6) than in *Sinanthropus*. In any case, the two indices show that in *Sinanthropus* and *Pithecanthropus* the calvarial vault is considerably less curved than in modern man in longitudinal as well as in transverse direction.

There are several methods whereby the degree of curvature of the frontal bone can be determined. Computation of the frontal curvature index (No. I 34) which expresses the ratio between the length of the chord and the length of the arc is the method most frequently used. In *Sinanthropus* this index amounts to 89.9, as against 85.7 in modern man; in the Ngandong skull the index is 89.5, which means that the frontal squama is flatter in *Sinanthropus* than in modern man. But, in evaluating these figures it should be remembered that in the case of

Sinanthropus the glabellar torus is included in the measurement, thus showing a smaller index figure for the curvature of the squama proper than would be the case if the torus had not been included.   G. Schwalbe (1902) attempted to exclude the torus from the calculation of the index by dividing the frontal bone into a glabellar portion and a cerebral portion; the cerebral curvature index (no. I 37) to correspond to the curvature of the squama proper, and the glabellar curvature index (no. I 36) to be used to estimate the prominence of the glabellar torus.   This cerebral curvature index amounts to 94.0 in *Sinanthropus;* in other words, when the glabellar torus is eliminated the curvature index increases considerably and the difference from modern man (index 85.7) becomes more conspicuous.   On the other hand, the glabellar curvature index of *Sinanthropus* amounts to 84.9 whereas in modern man in whom the torus is practically non-existent the same index totals only about 27.

Morant (1927) proposed that the flatness of the frontal bone be measured by drawing a subtense (st) from the vertex of the curvature to the n-b chord (cf. Fig. 183) and expressing the height of the subtense by the ratio between this height and the length of the chord.   Davidson Black adopted this measurement for *Sinanthropus*.   This "flatness index" (no. I 35) amounts to 16.4 in *Sinanthropus* against 22.9 in modern man and 17.4 in the Ngandong skulls, thus indicating that the frontal squama is considerably flatter in *Sinanthropus* than in modern man. Another way to determine the height of the vertex of the frontal curvature above the nasion-bregma line, as proposed by Morant, is to compute the angle formed by a line connecting the vertex of the curvature with the nasion and the nasion-bregma chord (cf. Fig. 183, Angle 6). This frontal curvature angle (no. A 6) grows the higher the vertex or the more the squama is curved.   It amounts to 20.2° in *Sinanthropus* against 26.8° in modern man; in the Ngandong skull it is the same as in *Sinanthropus* (20.5°).   However, neither Morant's flatness index nor Morant's frontal curvature angle provides an adequate measurement for the curvature in primitive hominids, for both measurements depend to a considerable extent upon the position of the nasion individually varying in relation to the glabellar torus.   If there is a deep notch at the nasion the nasion-basion line becomes shorter and the vertex of the curvature higher, though such a change in the nasion position cannot affect the curvature of the squama itself.

The parietal curvature index amounts to 94.1 in *Sinanthropus* against 89.4 in modern man. In *Pithecanthropus* II and in the Ngandong skull with indices of 95.9 and 95.7, respectively, the parietal bone is even flatter than in *Sinanthropus*.

The occipital curvature index is of particular interest since it reveals a condition of the occipital bone which is just the reverse of that of the remaining cranial bones.   The index totals 73.8 in *Sinanthropus* and 80.8 in modern man.   *Pithecanthropus* II with an index of 75.0, and the Ngandong skulls with an index of 75.7 follow the *Sinanthropus* line.   Therefore, the occipital bone is more curved in the primitive hominids than in modern man and stretches as the vault expands.   When the angle between the upper and the lower scale is measured the results are the same.   The occipital curvature angle of *Sinanthropus* is 103.2°.   In *Pithecanthropus* II the angle (103°) is almost the same, but in the Ngandong skull it is smaller (98.2°).   The difference in the conditions of the occipital bone is easily understood when one considers its position in relation to the direction in which the vault tends to expand.   The lower scale represents in primitive hominids a part of the base rather than of the vault, while the upper scale is entirely a part of the vault.   The more the bone participates in the formation of the vault the more it stretches (cf. Fig. 221) with the result that the distance from the opisthion to the lambda increases and, consequently, also the height of the vault.

The expansion of the vault and, in particular, the increase in height seem to necessitate a general prolongation of the individual bones in sagittal direction. To this the squama of the frontal bone contributes by adoption of a more erect position while the occipital bone stretches by adjusting its curvature angle. Therefore, the main share falls to the parietal bone which can meet the situation only by growing in length. This is exactly what the indices show. The frontosagittal arc index, that is, the length of the frontal arc in relation to the entire sagittal cranial arc, amounts to 36.5 in *Sinanthropus*, 35.5 in *Pithecanthropus* II, and 36.9 in the Ngandong skull but only to 34.6 in modern man. In other words, the relative share of the frontal bone is greater in *Sinanthropus* than in modern man. The same is true of the occipital bone with the corresponding indices totalling 34.5 in *Sinanthropus*, 33.4 in *Pithecanthropus* II, and 32.8 in the Ngandong skull against 31.1 in modern man. On the other hand, the sagittal arc index of the parietal bone amounts to 28.8 in *Sinanthropus*, 31.1 in *Pithecanthropus* II, and 30.3 in the Ngandong skull but to 35.4 in modern man. When the length of the sagittal arc of the parietal bone is compared with that of the frontal bone (frontoparietal arc index) the index amounts to 83.9 in *Sinanthropus* and 82.5 in the Ngandong skull against 102.2 in modern man. The parietal bone of modern man is, therefore, relatively much longer than the frontal bone. The relative shortness of the parietal bone in *Sinanthropus* in relation to the occipital bone and its increase in modern man can be gathered also from the parieto-occipital arc index which amounts to 119.7 in *Sinanthropus* but only to 87.6 in modern man. The fronto-occipital arc index shows that the frontal arc, in all the hominid groups, is longer than the occipital arc but that the differences in favor of the occipital arc are greater in *Sinanthropus* than in modern man (95.7 against 89.2); only the Ngandong skull (89.6) with its great variation in this feature (79.8–100.0) comes close to modern man.

It is worthy of mention that, despite the reported differences between the primitive hominids and modern man in the share the individual bones take in the sagittal cranial arc, each of these bones forms about one-third of the total arc. In *Sinanthropus* the frontal bone is the longest (index 36.5) and the parietal bone is the shortest (index 28.8) while in modern man the parietal bone is the longest (index 35.4) and the occipital bone the shortest (index 31.1). In the great apes there is a remarkable difference in favor of the frontal bones; the indices of the three bones are as follows: frontal bone—34.9; parietal bone—29.0; occipital bone—27.0. However, it is evident that this predominance of the frontal bone is due to the development of the glabellar torus and not to a greater sharing in the formation of the braincase itself.

The conditions of the vault as they are presented in the coronal sections and the share of the individual bones in them can be better demonstrated by craniograms (cf. Figs. 195, 199, 200) than by measurements. So far as the frontal bone is concerned, the rising of the squama makes room for the parietal bone which extends correspondingly farther forward; it is, therefore, to this bone that the task falls of filling up the space between frontal and occipital bones, not only in height but also in breadth. As is shown in Table III, the parietal bone of *Sinanthropus* is smaller, not only in the sagittal direction but also in the coronal one when compared with modern man. The average arc length of the coronal margin which can serve as measurement for determining the extent of the bone in that direction amounts to 103.4 mm. in *Sinanthropus* against 110.4 mm. in modern man. There is no particular difference in the development of the curvature itself, as expressed by the parietal tuberosity. Because of the parasagittal depression in *Sinanthropus* the bend of the bone seems rather more pronounced than in modern man. On the other hand, the temporal squama is very low in *Sinanthropus*. As is indicated in Table IX, its

average height totals only 34.5 mm. against 42.0 mm. in modern man. In proportion to the total length of the transverse cranial arc the parietal portion amounts to about 75 per cent in *Sinanthropus* and that of the temporal squama to about 25 per cent. In modern man the parietal part is a little smaller (about 72 per cent) and the temporal one correspondingly higher.

4. Position of the Occipital Foramen

Among the prescribed measurements of the calvaria, there is only one that can be used to calculate the position of the occipital foramen in relation to the total length of the skull. This measurement is the horizontal occipital length (no. M 10) and the occipital length index I (no. I 18). The figures represent the horizontal distance of the opisthion from the opisthocranion, with both landmarks projected to the Frankfort Horizontal, and its ratio in percentage of the maximum length, respectively. The lower the index the farther backward the position of the opisthion, and the higher the index the more forward. In *Sinanthropus* the average index amounts to 25.7 with a very narrow range (25.2–26.1) whereas in modern man it totals 30.6 with a range of 25.1 to 36.9. In *Pithecanthropus* II the index is 24.1 and in the Ngandong skull 25.5 (23.8–28.0). From these figures it may be deduced that the opisthion of *Sinanthropus* and the other primitive hominids is closer to the posterior end of the skull than is the case in the average of modern man. If, however, the distance of the opisthion from the opisthocranion is measured at the base of the nasion-opisthion line and, thereby, the orientation to the Frankfort Horizontal is eliminated, the figures are different. By using the nasion-opisthion line as base (cf. Fig. 180) the opisthocranion, projected to this base, falls, of course, beyond the opisthion and the more so the more the calvaria is posteriorly elongated. In cases in which the opisthocranion and the inion coincide, as it does always in *Sinanthropus*, the opisthocranion represents the farthest posterior landmark, regardless of the base taken as orientation. This is not true, however, of modern man (Fig. 185) where, in many instances, the opisthocranion appears only as the farthest posterior landmark of the calvaria when FH is taken as base. But if the nasion-opisthion line is used as base the utmost posterior point of the vault may again coincide with the inion or at least come very close to it, as it does in the Australian skull illustrated in Fig. 185. Under these circumstances the opisthion seems to occupy a position nearer to the posterior end of the skull. If the utmost posterior point falls beyond the opisthion, the occipital length index is designated by the sign "minus" (No. I 19). In *Sinanthropus* the average index amounts to −24.0, in modern man it totals −25.5, and if the opisthocranion—determined by FH as base—is taken as the utmost posterior point of the vault, only −21.8. In other words, the protrusion of the occiput behind the opisthion is more pronounced in *Sinanthropus* than in modern man, or else the occipital foramen occupies a more central position in *Sinanthropus*. This is true also of *Pithecanthropus* II with an index of −22.5, and still more so of the Ngandong skull with an index of −28.7. The minimum index of modern man that I was able to determine was −11.8. The first impression is, of course, that brachycranial skulls of modern man with a flattened occiput have the lowest index, but this is not necessarily so. The dolichocephalic Australian depicted in Fig. 185, for example, has an occipital length of −21.3 while the reconstructed *Sinanthropus* skull (Fig. 180) shows an index of −22.0. The position of the foramen seems, therefore, to be independent of the total length of the skull.

In the case of the Neanderthalians Boule (1911), using Topinard's method to determine the position of the occipital foramen of the skull of La Chapelle-aux-Saints, came to the conclusion that the foramen occupies a more backward position than is found in any case of modern man.

But this is erroneous, for despite the fact that in this skull the opisthion lies fairly well to the rear, it does not fall beyond the range of modern man. In the Rhodesian skull the foramen has an outspoken central position, notwithstanding the primitive character of the skull. S. Sergi (1930/32) in determining the position of the foramen of the Saccopastore Skull I found that it occupies an extreme forward position.

In the anthropoids the opisthion lies close to the utmost posterior point of the calvaria (Figs. 188–190). The occipital length index amounts to −6.4 with a very small range of variation. The difference between the anthropoids and primitive hominids in this respect is, therefore, much greater than in any other case: *Sinanthropus* and *Pithecanthropus* do not differ essentially from modern man. In *Pithecanthropus* IV, the position of the occipital foramen is, surprisingly, central (cf. Weidenreich, 1940a); in the reconstructed skull the index is still over −25, even with the enormous thickness of the occipital torus deducted. In the Ngandong Skull V, too, the index may amount to −33.0, and certainly is over −25 if allowance is made for the torus. In this feature the different stages of hominids, represented by fossil finds at hand, show no recognizable tendency to approach the anthropoids more and modern man less. I, therefore, consider the more central position of the occipital foramen, in obvious contrast to the conditions in anthropoids, as a specific hominid character.

Bolk (1917) has devoted an exhaustive study to this problem. He, too, attempted to determine the exact position of the occipital foramen within a basal plane of the skull although he did not choose the opisthion as landmark but the basion. Even if we ignore the fact that, in the case of *Sinanthropus*, the basion cannot be used for this purpose because it is missing in all specimens and because of the inaccuracy inherent in all constructions, the special position of the basion depends upon much more accidental factors than that of the opisthion. It depends on (1) the greatly variable length of the foramen; (2) the orientation of the foramen to the base; and (3) last, but not least, the size and length of the face. None of these three factors has any direct bearing on the position of the foramen itself and that of the opisthion with regard to the extent of the cranial base, but they affect the position of the basion in the sagittal as well as the vertical direction. Bolk tried to exclude from the measurement of the foramen position any line which might relate to the face and, therefore, particularly any line which starts from the nasion. Instead the base-line used should be exclusively dependent on the size and growth of the braincase. In order to achieve this postulate Bolk used as base-line the sagittal line that runs within the cranial cavity from the anterior end of its floor to the maximum of its width at the occipital pole. A vertical erected in the basion divides this base-line into anterior and posterior sections. The length of the latter section in proportion to the entire length represents Bolk's "index basalis." According to him, this index amounts to 46 in modern man, regardless of the special skull form. Of course, this index cannot be compared with the occipital length index obtained by the measurements recommended above.

Bolk was interested, above all, in the changes undergone by the position of the occipital foramen in the course of ontogenetic development. He found the foramen in a more anterior position in early childhood, shifting backward during the growth of the skull. The same conditions exist, he stated, in anthropoids. From these facts Bolk concluded that the extreme backward position of the anthropoid foramen is of a secondary nature, and that the main difference between man and the great apes consists in the fact that the apes lose the original central position while man keeps it. As it is Bolk's principle to consider all questions concerning human phylogenetic evolution exclusively from the ontogenetic viewpoint—in accordance with Haeckel's

axiom that ontogenetic stages are only a repetition of phylogenetic ones,—paleontologic facts pointing to the contrary are disregarded by him.   He overlooked, however, the fact that the more anterior position of the foramen in infantile man must be regarded as the mere consequence of the greater relative size of the brain and braincase and the smaller size of the face as compared with the conditions in the adult stage, and that these conditions are reversed in the anthropoids. I deem it unnecessary to dwell upon this point because I have discussed the entire problem in a previous publication (1940b) and shall briefly return to it later.

Bolk, in discussing the cause of the retrograde movement of the foramen during ontogenetic development, arrives at the conclusion that it is the growth of the face that is to be held responsible.   But such a statement lessens the value of his own investigation, for he originally set out to determine the exact position of the foramen in man and apes by choosing a fixed landmark (the basion)—that is to say, one that was completely independent of growth factors—only to find in the end that the position of the landmark selected was largely dependent upon just such factors.   Therefore, the basion should not have been used by Bolk for the designated purpose.   Yet he goes further in his conclusions and declares that, since the foramen occupies a more central position even in juvenile anthropoids, the erect posture of man cannot have had any influence on the adoption of this position, as is assumed by other authors.

Bolk is entirely right in suggesting that the backward movement of the foramen may have some connection with the eruption of the permanent dentition.   But this was already an established fact when Bolk wrote his article, for Keith had found (1910) that the posterior section of the cranial base (hormion-basion) increases after childhood in male gorilla by 120 per cent, in male orang-utang by 80 per cent, and in male chimpanzee by 70 per cent, against only 20 per cent in man.   On the other hand, it is also known that the increase in the braincase proper during the same time of life is smaller in apes than it is in man, the great increase of the calvaria of the former being almost entirely due to the development of the superstructures which, in turn, is dependent upon the development of the masticatory apparatus (cf. Fig. 203, and Krogman, 1931).   Therefore, the opisthion, since it belongs exclusively to the braincase, does not substantially change its place in relation to the opisthocranion while the basion does.   The real position of the occipital foramen can, consequently, not be determined by using the basion as landmark but by using the opisthion.   Of course, the development of the glabellar torus also affects the length of the nasion-opisthion line in its relation to the distance between opisthion and opisthocranion—more so in anthropoids and primitive hominids than in modern man.   But this interference has no decisive influence on the differences in the indices.   It can, therefore, be considered proved that, in hominids, irrespective of their special ranging within the evolutionary stage, the occipital foramen occupies a much more central position than it does in anthropoids.

Bolk denies that the central position has anything to do with the erect gait in man because of its occurrence in juvenile anthropoids.   There is, however, no need to point, in particular, to juvenile stages, for it is well known that in the entire primate group the occipital foramen is situated not at the very end of the base as in all other mammalian orders, but more or less anteriorly regardless of their special manner of locomotion.   Yet it is an established fact that in man the position is much more central than in any anthropoids, as the index figures given above incontestably prove.

In discussing this question one usually points to some of the platyrrhines, in which a pronounced central position seems to be obvious.   In order to verify the extent to which this claim

is justified I applied my method for the determination of the occipital length, as described above, to the skull of an adult male *Saimiri*. In Fig. 201, the craniogram, enlarged to four thirds its natural size, is depicted. It shows a surprising difference when the craniogram is compared with corresponding craniograms of anthropoids (Figs. 188–190). The cranial base really ends at the opisthion, and the occipital foramen, represented by the basion-opisthion line (ba-o), faces backward, though slightly, and in any case not downward or forward. The occipital bone rises at first vertically from the opisthion, and then bends sharply backward while the opistho-cranion coincides with the lambda. The vault as a whole seems, therefore, to be pushed rather backward than upward, as is the case in anthropoids and hominids. That this really occurs can be shown by the figures in Table XXX. The lambda vertical, which in anthropoids never

TABLE XXX

Selected Linear Measurements (CM), Angles (CA) and Indices (CI) of Some Platyrrhine Calvaria

CM	Calvarial Measurement	*Saimiri sciur.* ♂ No. 72081, AMNH	*Cebus cap.* ♀ No. 18943, AMNH	*Cebus cap.* ♂ No. 18945, AMNH	*Lagothr.* ♀ No. 91744, AMNH	*Lagothr.* ♂ No. 91746, AMNH	*Alouatta sen.* ♀ No. 76921, AMNH	*Alouatta sen.* ♂ No. 77804, AMNH	Anthropoids: Min.-Max.	Average
8	Nasion-basion line	36.5	52.5	55	62	68.5	60	75	—	—
9	Nasion-opisthion line	42.0	64	64.5	74	80	69	79	—	—
13	Bregma position projected to *n-o*	20.0	41	41	43	52	35	41	—	—
13a	Vertex position projected to *n-o*	32.0	41	43.5	46	55	48	52.5	—	—
14	Lambda position projected to *n-o*	51.0	68	69.5	76	82	65	72	—	—
44	Bregma height: above *n-o*	26.0	35	36	34	36	25	24	—	—
45	Vertex height: above *n-o*	27.5	35	36	34.5	36	27	25.5	—	—
46	Lambda height: above *n-o*	17.0	21	23	20	23	21.5	20	—	—
CA	**Calvarial Angles**									
11	Frontal inclination	52°	40°	41°	38°	35°	35°	30°	48°–58°	52.5°
12	Inclination of occipital bone	119°	103°	102°	97°	96°	80°	70°	80.4°–85.5°	83.1°
14	Cranial base	6°	8.5°	9°	8°	8°	8°	9°	8°–15°	10°
CI	**Calvarial Indices**									
11	Bregma height	62.0	54.7	55.7	45.9	45.0	36.3	30.4	41.4–50.8	46.1
12	Vertex height	65.6	54.7	55.7	46.6	45.0	39.1	32.3	50.6–56.2	54.0
13	Lambda height	40.5	32.8	35.7	27.1	28.7	31.2	25.3	43.3–45.7	44.7
16	Bregma position	47.7	64.2	63.7	58.2	15.0	50.6	51.8	30.0–38.1	35.3
16a	Vertex position	76.3	64.2	67.6	62.2	68.7	69.6	66.4	58.8–68.3	64.1
17	Lambda position	} 121.3	106.3	107.6	102.7	102.2	94.3	91.0	93.7–85.6	95.3
19	Opisthocranion position								105.9–107.2	106.4
43	Nasion-basion length	87.0	82.0	85.3	83.7	85.5	86.9	95.0	79.0–91.3	83.8

falls beyond the opisthion (lambda position index: 95.3) falls in Saimiri 21.3 per cent of the nasion-opisthion line beyond this landmark. On the other hand, the foot-points of the bregma and vertex, the position indices of which are 35.3 and 64.1 in anthropoids, are placed much farther back in *Saimiri* (indices: 47.7 and 76.3). In *Cebus* and *Lagothrix* the same conditions exist as in *Saimiri*. The expansion of the braincase and the way in which the expansion takes place depends principally on the relation between the size of the brain and the size of the body. *Saimiri* happens to be the primate in which the relative cranial capacity, expressed in percentage of the body weight, is highest, not excepting even man. According to Schultz' (1941) most

recent statement, the index of adult male and female *Saimiri* averages 3.04 as against 2.08 in adult male and female man, but against 0.57 in adult male gorilla, 0.86 in adult male and female orang-utang, and 0.865 in adult male and female chimpanzee. The diagrams in Figs. 202, 222 and 223 which are pictorial records of the figures in Tables XXX and XXVI–XXVII give height and position of bregma, vertex, and lambda above the nasion-opisthion line when the latter is reduced to 100 mm. and all distances are expressed by their indices as related to that line. Fig. 202 shows that the calvaria of *Saimiri* with a relative capacity index of 3.04 is the highest of the select platyrrhines while the male *Alouatta* with an index of 0.70 ranging only a little above the male gorilla, is the lowest. *Cebus* and *Lagothrix*, the former with a capacity index of 2.30, fit in between the two extremes. Furthermore, the diagram shows very impressively that, as is the case with the whole group of platyrrhines, the expansion of the braincase follows the same rule as in the anthropoid-hominid line (cf. Fig. 223): the frontal and occipital bones rise by turning about a transverse axis through nasion and opisthion; the frontal inclination angle increases from 30° in the male *Alouatta* to 52° in *Saimiri*; and the occipital angle increases from 70° in the male *Alouatta* to 119° in *Saimiri*. This resemblance is so great that even the inion which in male *Alouatta* is very close to the lambda shifts downward in *Saimiri* to halfway between lambda and opisthion (Fig. 202). Moreover, Figure 202 shows that the so-called cranial base, represented by the nasion-basion line, becomes shorter in about the same proportion as the vault expands and shifts closer to the nasion-opisthion line. In other words, since the distance ba-o corresponds to the length of the occipital foramen and the direction of the ba-o line indicates the orientation of the foramen with regard to the base of the calvaria, the foramen is found to be more toward the back the smaller the relative size of the brain and the more prognathous the face. I shall return to this relationship when I discuss the face. That the position of the basion, in contrast to that of the opisthion, is widely dependent on the development of the face, is demonstrated by the figures in Table XXX and the diagram of Figure 202.

Table XXX and Figure 202 illustrate also that the expansion of the braincase, although it follows in its general plan the same course as that of the anthropoid-hominid group, takes in development of individual traits a course characteristic of the platyrrhines. As was shown in the example of the *Saimiri*, the vault does not expand upward and forward but upward and backward, conforming to the posterior position of the bregma. The frontal bone developed, in all platyrrhines, a particular bregmatic process as a prolongation of the squama, which interposes between the two parietal bones. The general occurrence of this process, irrespective of the degree of expansion of the vault, seems to indicate that this may be the primary feature which has forced the vault to expand in the posterior direction.

Be this as it may, the central position of the occipital foramen in the platyrrhines, and especially in a species with a relatively high cranial capacity, is not exactly the same as that of man. I, therefore, believe that its special position in the hominids is due to their erect posture. I am borne out in this assumption by the surprising fact that, despite some evidently very primitive characteristics in the *Pithecanthropus* Skull IV, the foramen occupies in this skull a clearly central position. As I have pointed out in a previous publication (1940a), this peculiarity would agree very well with the perfectly human character of the Trinil femur, provided the femur really belongs to *Pithecanthropus*.

Several methods have also been recommended for determining the direction of the occipital foramen with regard to its orientation within the basal plane. But neither the inclination angle (No. 34 of R. Martin's list) nor Broca's second occipital angle (1875) meets all demands for

reliability. However, reliable results can be obtained if the angle is measured by using the nasion-opisthion, the nasion-basion, and the basion-opisthion lines as the three sides of a triangle with the nasion, basion, and opisthion as angles. As Figs. 180, 185, 188–190, and 203 show, the size of the nasion-basion-opisthion angle indicates the direction of the foramen. The use of this angle has, moreover, the great advantage that the angle can be measured without a goniometer or even a craniogram if the distances of the three landmarks are measured with a caliper or a slide compass. In the anthropoids the angle at the basion varies from 121° to 134° with an average of 127° while the average of modern man amounts to 156° with a variation ranging from 145° to 171°. In the reconstructed *Sinanthropus* skull the angle is 156° (variation 156°–159°) falling, therefore, entirely within the range of modern man; in the Ngandong skull the average is 154° (variation 152°–155°); in the Rhodesian skull the angle measures 153°; and in the skull of La Chapelle-aux-Saints 150°. These are all within the range of modern man. The angle is smaller the longer the nasion-basion line in relation to the nasion-opisthion line, and greater the shorter the nasion-basion line (Fig. 203). In the first case the foramen faces backward, in the second downward and forward when the skull is oriented in the Frankfort Horizontal. It can be considered a rule that the occipital foramen faces directly downward when the angle measures 150°; below this mark it faces backward, and above it forward. The length of the nasion-basion line is, as mentioned above and shown in Fig. 203, to a great extent dependent upon the size of the face in relation to that of the braincase. The smaller the braincase and the larger and more protruding the upper jaw, the greater its length, and conversely. The extent to which this correlation involves the size of the angle is revealed in a comparison of the relatively large-brained *Saimiri* with the small-brained male *Alouatta*. In the former the angle measures 142°, in the latter only 104°. It, therefore, seems quite natural that, in all hominids including *Sinanthropus*, the length of the nasion-basion line should amount to three-quarters of the length of the nasion-opisthion line whereas in anthropoids the ratio is much greater the nasion-basion line totalling 85 or more per cent of the nasion-opisthion line.

5. Position of Porion and Klition

It has long been known that in modern man the position of the porion varies greatly in relation to the total length of the skull. If the porion is regarded as fixed the pre- and post-otic portions are very different in length. There are cases in which the pre-otic portion is longer and others in which the post-otic portion predominates. According to R. Martin, the ratio between the two measurements varies from 44 to 61; since 50 represents the middle the prevalence of the post-otic portion is the usual condition. In all these calculations the position of the porion is computed in relation to the glabella-opisthocranion length. If, however, the nasion-opisthion length is again taken as basis, and the porion position determined on a mid-sagittal craniogram with its exact location projected to the mid-sagittal plane (Figs. 181–186) the foot-point of the vertical drawn from the porion projection to the base-line will indicate the distance from the nasion, and the extent of this distance in proportion to the entire length of the nasion-opisthion line will constitute the porion-position-length index. The length of the vertical indicates, on the other hand, the height of the porion above the base-line and its length in proportion to the entire length of this line the porion-position-height index (cf. Figs. 181–186).

Table XXXI contains the figures obtained by this method in measuring anthropoids, *Sinanthropus*, *Pithecanthropus*, the Ngandong skulls, Neanderthalians, and modern man. In the case of modern man the same skulls were used as had previously served for measuring the

TABLE XXXI

Position of the Porion in Relation to the Nasion-Opisthion Line (Minimum-Maximum Values and Indices)

	Anthropoids		*Pithe-can-thropus* II	4 *Sinanthropus*		4 *Homo soloensis*		5 Neanderthalians		Modern Man	
	Minimum-Maximum	Average		Minimum-Maximum	Average	Minimum-Maximum	Average	Minimum-Maximum	Average	Minimum-Maximum	Average
Nasion-opistion line	110–140	124	134	144–148	146	152–162	156	135–172	150	122–147	136.3
Foot position of the porion	70–97	84	92	96–106	102	105–112	145	95–115	103	85–108	94
Height of the porion	+2 to −9	−3.7	0	+1 to +6	+4.3	−2.0 to +5.5	+1.8	−1.5 to +7.5	+3.5	+5 to +16	+9.0
Porion position length index	64.2–73.3	67.6	68.6	66–71.6	69.6	68.5–72.7	69.8	67–69.3	68.9	64.8–74.5	69
Porion position height index	+1.6 to −8.6	−3.3	0	+0.7 to +4.1	+3.0	−2.0 to +5.5	+1.2	−0.9 to +5.0	+2.4	+2.8 to +10.9	+6.6

calvaria, according to my method described above. The figures concerning anthropoids refer only to female individuals in gorilla and orang-utang. Table XXXI reveals the fact, surprising at first glance, that in anthropoids as well as in hominids, regardless of their evolutionary stage, the porion is placed considerably behind the middle, that is to say much closer to the opisthion than to the nasion; in other words, the pre-otic section is much longer than the post-otic one. The differences between anthropoids and hominids, and also between the different evolutionary stages of the hominids are so minimal that they can be disregarded, the more so since the minimum-maximum values are almost the same in anthropoids and in modern man. Therefore, the differences in the porion position within the modern-man group, related to the maximum length of the skull (glabella-opisthocranion), are not due to an unstable position of the porion itself but to variations of the skull length which, in turn, are dependent entirely on the flatness or elongation of the occiput.

The height of the porion position is much more important than its length position. Table XXXI and Fig. 203 show that in anthropoids the porion lies below the base-line (the porion-position-height index is negative: average −3.3) while it is above it in modern man (the index is positive: average +6.6) and in *Sinanthropus* still higher (index +3.0); but in some of the primitive hominid group the height index of modern man is already reached. The figures reveal, therefore, the clear tendency of the porion to rise from a lower to a higher level during human evolution. That such a trend is indeed at work can also be demonstrated by determining the position of the internal auditory porus (Figs. 203 and 181). If the contour of the porus in its projection to the mid-sagittal plane is traced out in the craniogram, the internal porus appears at the same level as the porion in the gorilla (Fig. 203) and in *Sinanthropus* Skull III (Fig. 181) while it is on a much higher level in modern man (Fig. 203). Thus, not only the porion but also the entire pyramid rises and, in addition, in the latter case the median portion ascends more than the lateral one.

This rising is apparently in part a phenomenon of the transformation of the skull base. It has already been noted that the nasion-basion line undergoes a characteristic reduction in length. In the great apes (males gorilla and orang-utang excluded) its length amounts, on the average, to about 85 per cent of the length of the nasion-opisthion line while it is about 75 per cent in the hominids. In the male gorilla this difference is greater; for instance, in the specimen depicted

in Fig. 203 the percentage totals 89.0 as against 77.5 in the depicted European skull. This reduction is obviously the result of the well-known deflection of the base which takes place in man although it is completely lacking, or at best only faintly indicated, in apes. In the male gorilla (Fig. 203) the floor of the cranial cavity in front of the basion ascends gradually in a perfectly straight line, then slopes rather abruptly to the olfactory recess. The klition that marks the passage from the clivus proper to the sella turcica is indicated only by a very faint elevation while the posterior clivoid processes and the dorsum sellae are completely missing. In other cases there may be a dorsum, but this dorsum is a thin piece of bone and appears to be placed, accidentally, on a more or less even slope as an independent structure rather than as an essential piece of the base. In modern man (Fig. 203) the klition marks the apex where two planes meet; the posterior one, the clivus in the strict sense, slopes toward the occipital foramen, the anterior one toward the foramen caecum. The angle formed by the two planes represents the deflection angle of the base, amounting to about 135° (cf. R. Martin, 1924; p. 891). The strong sellum appears here as an elevated part of the base itself.

The shortening of the nasion-basion line in modern man, as discussed above, is chiefly the result of the deflection of the base. The deflection itself is brought about by the base being pushed toward the interior of the cavity as the entire skull rolls up. In *Sinanthropus* the central part of the cranial base is missing in all specimens. It is therefore impossible to determine directly the position of the klition and so to find out whether or not a deflection existed. However, as Fig. 203 shows, there is a clear correlation between the position of the klition and that of the internal auditory porus, which is preserved in its natural position in several *Sinanthropus* skulls. As was mentioned above, the porion and the internal porus have moved upward and forward from the nasion-opisthion base-line if the conditions of the anthropoids are taken as primary. This movement parallels the rising of the klition, that is, the development of the deflection. In *Sinanthropus* Skull III the porion and the internal porus are, as a rule, at the same level of the base-line (Fig. 181) and the porus only slightly above it. This certainly indicates that the deflection existed in its early stage.

In the description of the individual bones I have shown that the configuration of the bases of the tympanic and the pyramid of *Sinanthropus* resembles that of the anthropoids much more than that of modern man since they are flat and extended in the former while they appear to be compressed and set on the edge, as it were, in the latter (cf. Fig. 172, A-C). This is the result of the rising of the entire pyramid, as indicated by the upward shift of the porion and internal porus. How great this dislocation really is can easily be estimated on the basis of the change which the course of the superior border of the pyramid has undergone. In Fig. 203 this border (msp) is traced out in its entire length from the apex of the pyramid to its base at the cranial wall, as it appears in projection to the mid-sagittal plane. In the depicted gorilla the border begins a little above and in front of the porion and ascends rather steeply toward the wall in a slightly backward direction. In modern man the border begins high above and far in front of the porion and runs lateralward and backward in a much more horizontal line.

The deflection of the base as it appears in mid-sagittal sections is, of course, not restricted to the mid-line, as exposed by such a section, but extends laterally to either side. It follows an oblique line, running laterally and backward from the pre- and post-sphenoid junction to the external ear opening. In 1924(b), when I first described the transformation of the human skull as an adaptation to the erect posture I wrote: "If one observes the braincase with its single components, as it bends around the indicated line as axis, the petrous bone and the tympanic

appear to be jammed between the anterior portion of the temporal squama and the greater sphenoid wing in front, and the mastoid portion and the lateral parts of the occipital in the rear. At the same time they are lifted toward the interior of the cranial cavity. The originally horizontally oriented tympanic plate undergoes a rotation and finally stands vertically. The mandibular fossa serving as an abutment for the mandible apparently plays an essential rôle in this transformation."

To revert to the question of whether or not the central position of the occipital foramen has something to do with the erect posture it is possible, I think, to answer this more accurately now. It is evident that the position itself cannot be the result of erect stance and gait but rather of the expansion of the braincase in a relative sense (cf. the platyrrhines) or in an absolute one (cf. man). However, the deflection of the base and the rolling-up of the skull about the described transverse axis can only be conceived as an adaptation to the upright posture. *Indris, Ateles, Hylobates,* and chimpanzee can stand and walk in erect position without having the occipital foramen placed in the center of the base. But in all these cases the erect position is only assumed occasionally, the habitual locomotion being executed by climbing or swinging. In man, however, erect stance and gait have become the common form of locomotion to which the skeletal parts of the trunk and limbs are completely adapted. The adaptation of the skull consists in the development of the features described above. Hence, the central position of the occipital foramen alone is not a sufficient indicator of erect position and, conversely, its more backward location does not preclude the possibility of standing and walking upright. Broom (1939a) and Dart (1929) incline to the assumption that the *Australopithecidae* were already erect. Both authors come to this conclusion chiefly on the basis of geological data. The skull fragment of *Paranthropus robustus Broom* shows an incontestably rearward position of the occipital foramen, such as occurs in the chimpanzee, and the tympanic and porion portion of the temporal bone are more ape-like than human (unfortunately the clivus region is missing). *Paranthropus* may, nevertheless, have been able to assume an upright posture. On the other hand, *Sinanthropus* was certainly an erect-standing and walking creature, as is proved by the morphological character of the femur (Weidenreich, 1941a). Its skull, however, is only in a state of transformation but not yet as fully adapted as in modern man; the erect position has obviously developed far ahead of the transformation of the skull.

IV. METRICAL APPEARANCE OF THE FACE

1. The Facial Triangle

The frame of the face and its size and proportions, seen in mid-sagittal sections through the skull, can best be determined by measurement of the facial triangles using the nasion-basion line (n-ba) as their base. Three triangles can be distinguished: (1) the upper facial triangle with the prosthion as vertex and the nasion-prosthion (n-pr) and basion-prosthion (ba-pr) lines as sides; (2) the total facial triangle with the gnathion as vertex and the nasion-gnathion (n-gn) and the basion-gnathion (ba-gn) as sides; and (3) the nasal triangle with the nasospinale as vertex and the nasion-nasospinale (n-ns) and the basion-nasospinale (ba-ns) lines as sides. The angles at the nasion are the only measurements which give an accurate picture of the prognathism of these different parts of the face.

The angle ba-n-pr corresponds to the "facial profile angle" (cf. Figs. 180, 185), but its value cannot be compared with that of the classical profile angle which has the Frankfort Horizontal

as base-line and is represented by the angle at the prosthion. In the reconstructed *Sinanthropus* skull (Fig. 180) the facial profile angle (no. I 1, Table XXXIII) measures 84.5° while the facial triangle angle at the nasion totals 72° (no. I 2, Table XXXIII). In modern man the former angle varies from 70° to 99° with an average of 83.5°, and the latter from 54° to 76° with an average of 67°. Because of the differences in the methods used and the different values of the angles obtained the classification usually applied must be changed when dealing with the facial angle. I, therefore, propose the following determination:

	Triangle-Method	Old Method
Hyperprognathous	over 75°	below 70°
Prognathous	75°–70°	70°–80°
Mesognathous	70°–65°	80°–85°
Orthognathous	65°–60°	85°–93°
Hyperorthognathous	below 60°	over 93°

Sinanthropus belongs to the mesognathous group when classified by the old method, but to the prognathous group by the triangle method. The average of modern man is mesognathous by both methods. In anthropoids the angle varies from 30° to 68° with an average of 52.3° according to the old method, and from 92° to 114° with an average of 100° according to the triangle method. In both cases the anthropoids are hyperprognathous.

When the facial triangle is used for the determination of the nasal profile angle the same differences occur. In *Sinanthropus* the angle measured by the old method amounts to 89° (no. I 5, Table XXXIII); it varies in modern man from 73° to 100° with an average of 86.6°. Measured by the triangle method the angle totals 66° in *Sinanthropus* and 65.7° in modern man with minimum-maximum values from 53° to 73° (no. I 6, Table XXXIII). In the first case *Sinanthropus* and modern man fall within the orthognathous group; in the second case *Sinanthropus* is mesognathous and only modern man orthognathous. The anthropoids with an average of 92° and a minimum-maximum value of 86° to 97° are hyperprognathous in all cases.

Application of the facial triangle in determining the nasal profile angle brings to light a new fact. R. Martin (1924), following Broca's directions, takes as "nasospinale" (ns) not the most salient point (since the degree of development of the nasal spine varies) but the point "where a line tangent to the two lateral curves of the lower margin of the piriform aperture crosses the median line" (Wilder); that is, the base of this process at the threshold of the nasal floor is taken as the most salient median point. In modern man the nasal profile angle, when measured by the old method, appears in most cases to be greater—tending more to orthognathy than does the facial profile angle. This is, of course, due to the more rearward position of the nasospinale in its orientation to the main profile line (running from nasion to prosthion). Such a condition is the rule in anthropoids (Figs. 188–190). One may object that a nasospinale does not exist in anthropoids because there is no anterior nasal spine. This presumption is correct, however, only if the conditions obtaining in modern man are accepted as standard for all primates. But in anthropoids, too, the entrance to the nasal floor proper is marked by a transverse ridge at the upper end of the prenasal sulcus behind which the nasal floor drops suddenly. In the middle of this ridge there is frequently a distinct, more-or-less pointed elevation which obviously corresponds to the nasal spine of modern man. This anthropoid "nasospinale" always lies behind the prosthion and the nasion-prosthion line (cf., in particular, Fig. 203) and, consequently, the nasal angle of the nasal triangle is always smaller than the nasal angle of the upper facial triangle.

But it happens not infrequently in modern man that the nasospinale juts out beyond the nasion-prosthion line. This may occur even if, as is advocated, the base of the nasal spine is taken as the nasospinale. The European skull depicted in Fig. 203, for example, and that of the Australian in Fig. 185 represent such cases. Figure 203 also explains these seemingly reversed conditions. The prosthion has apparently shifted farther backwards than the nasospinale during the reducing process of the maxilla; in other words, the alveolar process that carries the teeth has undergone a more extensive reduction than have the upper parts of the face, as represented by the frame of the piriform aperture. Expressed in terms of the usual nomenclature, there is, therefore, in this case no alveolar prognathism but a distinct, though slight, nasal prognathism. If the tip of the nasal spine rather than its base is taken as landmark the difference between the alveolar and nasal prognathism is much greater. Viewed from the phylogenetic viewpoint

TABLE XXXII

Linear Measurements (FM) of the Hominid and Anthropoid Face

FM	Facial Measurements	Symbols and Key Numbers to R. Martin's List	Anthropoids	Sinan-thropus	Neanderthal					Modern Man
					Rho-desian	La Cha-pelle	Gibral-tar	Tabūn I	Skhūl V	
1	Superior facial length: *ba-pr*	40		114	115	124.8	108	(102)	115	Individuals: 76–124; Rac. groups: 87.2–107.6; Eskimo: 107.6
2	Lat. facial length: *fmo-po*	41		83	73	83	81	—	83	
3	Superior facial breadth: above *fmt-fmt*	(43)	Individ.: 73–142; aver. 106	121	140	128	118	112 '	120	
4	Inner biorbital breadth: *fmo-fmo*	43(1)	Ind.: 63–122; aver. 91.0	111	123	112	106	102	(111)	
5	Biorbital breadth: *ek-ek*	44		111	120	112	102	—	—	
6	Naso-malar arc: *fmo⌒fmo*	44(1)		119	134	—	—	—	—	
7	Bizygomatic breadth: *zy-zy*	45		148	(147)	153	(134)	(130)	145	Ind.: 101–155; Rac. groups: 114.4–146; Eskimo: 145
8	Maxillary breadth: *zm-zm*	46		98(?)	110	110	103	—	110	Ind.: 79–108; Rac. groups: 88–102.1
9	Bimalar breadth: *tm-tm*	46a		93	—	—	—	—	—	
10	Superior facial height: *n-pr*	48		77	95.2	86	78.5	79	73	Ind.: 53–84; Rac. groups: 60.2–77.0; Eskimo: 77
11	Alveolar height: *ns-pr*	48(1)		25	32	29	25	23	—	
12	Orbito-alveolar height	48(3)		44	56	48	—	46	—	
13	Post. interorbital breadth: *la-la*	49		30	34	—	24.8	(28)	(24)	
14	Distance between the two optic foramina	49(3)	O. 20 / G. 35 }(W) / Ch. 24	30	—	—	—			23.3 (St. Oppenheim)
15	Ant. interorbital breadth: *mf-mf*	50		25	28	—	26	32	(28)	Rac. groups: 19.3–21.7
16	Orbital width	51		44 (*mf*) 40 (*la*)	51	47	46	(42)	46	Ind.: 30–47; Rac. groups: 38–44; aver. 41.4; Ind.: 34–49; Rac. groups: 37.4–43; aver. 39.5
17	Orbital height	52		36	39	37	39	(33)	(30)	Ind.: 19–41; Rac. groups: 30–35.1; aver. 33.4
18	Length of orbital floor	53		47	54	—	56	—	—	Indiv. Japanese: 43–53; 49.2; Races: 46.3–49.2; 47.4 (Opp.)
19	Length of lat. orbital wall	—		47	53	—	55	—	—	Ind. Japanese: 41–53; 48.3; Races: 44.7–48.3; 46.3 (Opp.)

TABLE XXXII (*continued*)

FM	Facial Measurements	Symbols and Key Numbers to R. Martin's List	Anthropoids	*Sinan-thropus*	Rho-desian	La Cha-pelle	Gibral-tar	Tabūn I	Skhūl V	Modern Man
					Neanderthal.					
20	Length of med. orbital wall	—		46.5	47	49	—	—	—	Ind. Japanese: 36–47; 41.7; races: 41.7–48; 45.0 (Opp.)
21	Length of orbital roof: inferior margin / superior margin	—		57 / 63.5	65	65	63	—	—	Ind. Japanese: 46–57; 51.8; races: 48.6–51.8; 50.1 (Opp.)
22	Capacity of the two orbits in cc.	53(3)	Ind. (Chimp.) 31–102; aver. 57	74	86	78	—	—	—	59.5
23	Nasal width	54		30	31.1	34	34.5	(34)	(28)	
24	Nasal height: *n-ns*	55		52.5	59	61	58.5	58	(53)	
25	Height of pirif. aperture	55(1)		33	(32)	—	—	—	—	
26	Length of nasal bones (chord)	56		20	27?	—	—	—	—	
27	Length of nasal bones (arc)	56(1)		21.5	30?	—	—	—	—	
28	Length of lat. margin of nasal bone	56(2)		22	31	29	24.5	25	—	
29	Least breadth of nasal bones	57		14	12.5	14	14.5	(20)	7.2	
30	Greatest breadth of nasal bones	57(1)		18	20?	21	—	—	—	
31	Superior breadth of nasal bones	57(2)		18	14	—	—	—	—	
32	Inferior breadth of nasal bones	57(3)		15?	20?	21	—	—	—	
33	Maxillo-alveolar length: *pr-alv*	60		64	67	70	—	—	65.5	Ind.: 44–65; Rac. groups: 49–57
34	Maxillo-alveolar width: *ekm-ekm*	61		71	(78)	71	—	—	69.5	Ind.: 50–72; Rac. groups: 58–69
35	Post. maxillo-alveolar width	61(1)		66	60	—	—	—	—	
36	Ant. maxillo-alveolar width	61(2)		46	55	—	—	—	—	
37	Palatal length: *ol-sta*	62	32–45 av. 40.7	52	57.7	62	—	—	60	
38	Palatal breadth	63		39	48.6	50	—	—	45	Ind.: 33–48; Rac. groups: 36–43
39	Palatal height	64	13–21 av. 17.7	12	19.2	—	—	—	18.0	Ind.: 6–21; Rac. groups: 9–15
40	Total facial height: *n-gn*	47		118	—	131	—	118	126	Ind.: 90–138; Rac. groups: 111–126
41	Inferior facial length: *ba-gn*	42		106	—	—	—	108	118	—
42	Bicondylar breadth	65		124	—	—	—	133	132	
43	Bigonial breadth	66		103	—	—	—	93	98	Ind.: 65–126; Rac. groups: 88–112

Broca-Martin's directions for locating the nasospinale are wrong; for compared with the anthropoids the tip of the human nasal spine marks, somehow, the "original" foremost extent of the lower border of the nares behind which the alveolar process has retreated as a result of the reduction of the masticatory apparatus. We can therefore consider the nasal angle of the nasal triangle to be greater than the nasal angle of the upper facial triangle as a specific feature of modern man; in anthropoids and *Sinanthropus* it is smaller. In the Neanderthal group (cf.

TABLE XXXIII

Angles (FA) and Indices (FI) of the Hominid and Anthropoid Face

FA	Facial Angles	Symbols and Key Numbers to R. Martin's List	Anthropoids	Sinanthropus	Neanderthal — Rhodesian	Neanderthal — La Chapelle	Neanderthal — Gibraltar	Neanderthal — Tabun I	Neanderthal — Sküll V	Neanderthal — Aver.	Modern Man* — Average	Modern Man* — Minimum-Maximum Values Various Races
1	Facial profile angle to FH	72	41–56° Ind. 30–68° av. 52.3°	84.5°	84°	82°	88°	92°	(88°)	86.8°	83.5	Rac. groups: 76.8°–89.2° Individuals: 70.0°–99.0° Chinese: 83.0°
2	Nasion angle of the upper facial triangle: ba-n-pr	72(5)	92–114° av. 100°	72°	67°	70°	67°	60°	81°	69°	67.0°(W)	Mongol groups: 84.0°–85.0° 54.0°–76.0°(W)
3	Prosthion angle of the upper facial triangle: ba-pr-n	72(5)	33–48° av. 42°	68°	63.5°	68°	72°	78°	59°	68.1°	69.3°(W)	Rac. groups: 65.6°–76.5° (Rivet); 61.0°–83.0°(W)
4	Basion angle of the upper facial triangle: n-ba-pr	72(5)	31–43° av. 38°	40°	49.5°	42°	41°	42°	40°	42.8°	42.0°(W)	36.0°–50.0°(W)
5	Nasal profile angle	73	Ind. 43–76° 51–69° av. 62.8°	89°	85°					—	86.6°	Rac. groups: 80.5–90.3° Individuals: 73.0°–100.0° Mongol groups: 86.0°–89.2°
6	Nasal angle of the nasal triangle: n-ns-ba	—	86–97° av. 92°	66°	69°	76°	76°	—	70°	72.7°	65.7°(W)	53.0°–73.0°(W); in most cases greater than No. 2
7	Alveolar profile angle	74	31–47° Ind. 10–55° av. 38.2°	72°	85°					—	74.2°	Rac. groups: 62.0–86.0° Individuals: 49.0°–100.0°
8	Profile angle of nasal roof to FH	75	58° (G) 87° (Ch.) av. 67°	69°	73°					—	62.0°	Mongol groups: 70.0°–79.2° Rac. groups: 53.2°–68.3° Individuals: 43.0°–76.0°
9	The same to n-pr line	—	+1.5°(G) —25°(O) av. —9.7°	16°	12°					—	20.1°	Mongol groups: 66.4°–68.3° Rac. groups: 12.1°–34.3° Individuals: 47.0°
10	Molar profile angle	76	67–110° av. 95° (Opp.)	106°	108°					—	114.5°	Mongol groups: 16.1°–19.5° Racial groups: 109.0°–120.0° Buriats: 109.0°
11	Vertical inclination angle of orbit	78	55–93° (Opp.) av. 80° (Opp.)	111°	—				103°	—	92.1°	81.0°–105.0°—all races (Opp.)
12	Frontal inclination angle of orbit	78(1)	G. 5° O. 0° Ch. 0°	11°	7°					—	17.5°	Rac. groups: 14.2°–21.0° Individuals: 9.0°–28.0° Mongol groups: 14.2°–15.0°
13	Horizontal inclination angle of orbit	78(2)	G. 0° O. 0° Ch. 3°	10°	3°					—	12.6°	5°–21° (Opp.) Japanese: 13.1° (Adachi)
14	Angle of orbital axes	78(3)	G. 35° O. 30° Ch. 40°	52°	50°?					—	41.0° Japanese: 40.3° Europeans: 41.7°	Japanese: 32°–51°; (Adachi)
15	Nasion angle of total facial triangle: ba-n-gn	72(5)	68–84° av. 78.5°	56°	—			50°	62°	56°	60.0°(W)	54.0°–63.0°(W)
16	Gnathion angle of total facial triangle: ba-gn-n	72(5)	37–47° av. 42°	58.5°	—			64°	47°	55°	51.0°(W)	45.0°–56.0°(W)
17	Basion angle of total facial triangle: n-ba-gn	72(5)	50–66° av. 59°	65.5°	—			66°	71°	68.5°	69.0°(W)	63.0°–76.0°(W)

TABLE XXXIII (continued)

FA	Facial Angles	Symbols and Key Numbers to R. Martin's List	Anthropoids	Sinanthropus	Neanderthal.						Modern Man*	
					Rhodesian	La Chapelle	Gibraltar	Tabūn I	Skhūl V	Aver.	Average	Minimum-Maximum Values Various Races
18	Inclination angle I of mandibular front	72(5)	av. 57°	26°	—	—	—	—	—	—	20.0°(W)	—
19	Inclination angle II of mandibular front	—	av. 93°	84.5°	—	—	—	—	—	—	71.0°(W)	—
FI	Indices											
1	Superior facial I	48/45	c. 70	52.1	64.6	56.1	58.5	60.8	50.3	58.1	53.2°	Rac. groups: 49.0°–57.4°; Mongol groups: 52.7°–57.4°
2	Superior facial II	48/46	—	78.5?	86.3	78.1	76.2	—	66.4	76.8	—	Rac. groups: 73.9°–93.2°
3	Zygomatico-malar	46/45	—	66.2	75.0	71.9	76.9	—	75.9	74.9	mf 83.5	Rac. groups: 78.8°–95.3°
4	Orbital	52/51	Ind. 75.6–119.4 av. 101	mf 81.9 la 90	76.4	78.7	84.8	78.5	65.3	76.7	la 87.1°	Rac. groups: 18.2°–22.2°
5	Interorbital	50/43	Ind. 13.3–37.0 av. 22.4	22.5	22.8	—	24.5	31.3	28.3	26.7	20.1°	Battak: 20.1°; Birman: 20.6°
6	Naso-malar	44(1)/44	—	107.3	111.5	—	—	—	—	(111.5)	102.0°	Rac. groups: 105.9°–113.0°; Mongol groups: 106.0°
7	Nasal	54/55	Ind. 25.4–57.4 av. 40.8	57.2	52.8	55.7	59.0	58.6	52.7	55.7	50.0°	Rac. groups: 38.9°–60.2°; Tasmanian: 57.4°
8	Index of apert. pirif.	54/55(1)	—	90.8	97.3	—	—	—	—	(97.3)	70.0° Negroes: 100.0°	Australians: 82.0°–130.0°
9	Maxillo-alveolar	61/60	Ind. 52.1–106 av. 76.1	107.6	116.2	101.2	—	—	106.0	107.8	117.5°	Rac. groups: 108.2°–126.0°
10	Transverse palato-facial	61/45	—	47.9	53.0	46.3	—	—	48.0	49.1	—	—
11	Longitudinal palato-facial	60/40	—	56.2	58.3	56.0	—	—	56.9	57.1	—	—
12	Palatal	63/62	Ind. 34.5–62.5 av. 49.3	75.1	84.6	80.6	—	—	75.0	80.1	79.1°	Rac. groups: 63.6°–94.6°
13	Palatal height	64/63	40–56 av. 46	30.7	39.5	—	—	—	40.0	39.7	31.4°	Rac. groups: 26.1°–36.7° Individuals: 21.0°–55.0°
14	Total facial	47/45	90–100	79.7	—	—	—	91.0	87.0	87.9	88.1°	Rac. groups: 74.0°–94.0°
15	Zygomatico-suprafacial	43/45	—	81.7	95.4	83.7	—	86.2	82.8	87.0	—	—
16	Zygomatico-mandibular	66/45	—	69.6	—	—	—	71.4	67.5	(69.4)	76.0°	Rac. groups: 67.5°–87.5° Ambitlé: 70.0°
17	Facial module	40+45+47/3	—	127	—	136.3	—	116.7	128.7	127.2	—	45.0°–60.0°
18	Longitudinal cranio-facial	1/C1	over 100	58.8	54.8	60.0	54.3	55.7	60.0	57.0	52.0°	Rac. groups: 87.0°–102.2° Eskimo: 100.0°–102.0° East Chukchi: 102.2°
19	Transverse cranio-facial	7/C20	Ind. 97.9–179 av. 136	105.7	101.8	98.2	89.8	92.3	101.2	96.6	93.8°	—
20	Vert. cranio-facial	10/C34	90–105 av. 95	66.8	73.6	61.8	63.3	68.6	56.6	65.0	51.0°	—
21	Zygomatico-frontal	C23/7	—	64.7	70.8	72.6	—	74.5	72.3	72.5	72.0°	Rac. groups: 66.2°–91.1°; Certain Mongol groups: 66.2°–68.7°
22	Cephalorbital	—	14.2	7.3	6.5	4.7	—	—	—	—	all races: 4.2°	—

* Unless otherwise indicated, after R. Martin.

Table XXXIII) only Skhūl V follows the primitive pattern in this respect; the conditions of the others are as those of the majority of modern man. As Fig. 203 demonstrates, the decrease of the two angles at the nasion (ba-n-pr and ba-n-ns) when comparing modern man with gorilla is much greater in the upper facial triangle than in the nasal triangle measuring 47° in the case of the former but only 37° in the latter, even though the base of the nasal spine and not the tip has been used as landmark. The difference in favor of the nasospinale angle would, of course, have been even greater had the tip been used. It is thus apparent that in the reducing process of the maxilla the alveolar process is, as a rule, far more involved than the body of the maxilla.

This is true not only of the maxilla but also of the mandible, as is shown by the conditions of the gnathion angle within the total facial triangle. This is not the place to enter into a discussion of the mandible and the transformation of its frontal region. All that can be said on this problem, on the basis of the *Sinanthropus* finds, has been said in a previous paper dealing with the *Sinanthropus* mandible (1936b), and the more general questions have been analyzed in another previous publication (1934) to which the reader is referred. However, when the mandible is not dealt with as a separate element but as an integral part of the facial skeleton the problem is a different one. For this purpose only those crania can be used in which the teeth, particularly the front teeth, are not broken off, lost, or worn to such an extent that the occlusion has lost its original character.

In drawing the total facial triangle either the incision or the gnathion can be used as apex. With the incision as apex the divergence of the upper facial triangle is found to be minimal and the results not more elucidating than those achieved by using the prosthion since the size of the angle at the incision depends more or less on the size of the prosthion angle. It is quite different when the gnathion is used as apex, for this point marks the greatest height of the face. The nasion angle of the total facial triangle, therefore, shows the extent to which the mandibular base projects beyond the cranial base (represented by the nasion-basion line) while the angle at the basion shows how far the mandibular base reaches downward. The diagrams in Fig. 204 represent the upper facial and the total facial triangles of *Sinanthropus* (reconstructed skull), *Pithecanthropus* IV (reconstructed skull), the average of modern man, and the average of the anthropoids.

The nasion angle of the total facial triangle (ba-n-gn) (no. A 15, Table XXXIII) measures 56° in *Sinanthropus* and 60° in modern man but 78.5° in anthropoids. The retraction of the mandibular base appears, therefore, to be less pronounced in modern man than in *Sinanthropus*. But this is, or course, only due to the small number of human skulls used for the measurements of the triangle and the accidental fact that there were more individuals among them with long mandibles than with short ones. In any case, the figures show that the gnathion has retreated less than the prosthion. If the anthropoid average is taken as the basic figure the prosthion will be found to retreat in proportion to the decrease of the angle at the nasion from 100° in anthropoids to 71° in *Sinanthropus*, and 67° in modern man; or 29° in *Sinanthropus* and 33° in modern man whereas the decrease at the gnathion amounts to only 22° in *Sinanthropus* and 18° in modern man.

There is, on the other hand, a characteristic change in the height conditions. If the distance nasion-gnathion represents the height of the face, regardless of whether the nasion-gnathion line runs vertically or in an obliquely forward direction, the height approaches the vertical the nearer it comes to the base-line (nasion-basion), or the smaller the angle at the nasion (cf. Fig. 204). If there is no reduction in the length of the mandible the height of the face increases in

accordance with the decrease of the angle at the nasion; in other words, when the angle at the nasion decreases the angle at the basion increases (no. A 17, Table XXXIII). In anthropoids the angle at the basion measures 59°, in *Sinanthropus* 65.5°, and in modern man 69°. The same proportions obtain when the basion-gnathion distances are brought in relation to the length of the base-line. The basion-gnathion index totals 143 in anthropoids, 96 in *Sinanthropus*, and 111 in modern man.

When the nasion angle of the upper facial triangle is compared with that of the total facial triangle the difference amounts to 15° in *Sinanthropus*, 21.5° in anthropoids, and 7° in modern man. The reduction of the mandibular length decreases as the maxillar length is reduced. But the gnathion retreats less than the prosthion. The adjustment of the two jaws is achieved by the retroversion of the front part of the mandible. As I have pointed out in a paper on the *Sinanthropus* mandible (1936b), the inclination of the front part can best be determined by measuring the angle which the incision-gnathion line forms with the alveolar plane. Another method is to determine the angle that this line forms with the nasion-gnathion line (no. A 18, Table XXXIII). Angle I measures 26° in *Sinanthropus*, 20° in modern man, and 51° in anthropoids; angle II measures 84° in *Sinanthropus*, 71° in modern man, and 93° in anthropoids (cf. Fig. 204). The reduction of these angles proceeds concurrently with the reduction of the length of the entire face. But the figures reveal that a process has taken place, similar to that occurring in the reduction of the maxilla (see above), in which the prosthion retreated more than the naso-spinale as a result of the diminution of the alveolar process being more pronounced than that of the body of the maxilla. That a chin (mentum osseum and mental tubercle) has developed in modern man while it is missing or just faintly indicated in *Sinanthropus* is due to the fact that not only has the mandible become shorter, but the alveolar process has retracted along the incision-gnathion line thus augmenting the prominence of the base represented by the gnathion. The alveolar reduction, like that of the maxilla, is due chiefly to the decrease in size and strength of the front teeth, particularly of their roots (cf. Weidenreich, 1932 and 1936b). The chin must, therefore, be regarded as equivalent to the nasal spine, both features being relatively fixed "basal" points on which the lower and upper alveolar processes turn back.

As Fig. 204 further reveals, the incision extends farther forward than does the prosthion. If n-ba equals 100 the basion-prosthion line measures 145 in anthropoids, 119 in *Pithecanthropus* IV, 100 in *Sinanthropus*, and 97 in modern man while the nasion-incision line totals 156, 126, 99, and 105, respectively, when the occlusion is perfect. These differences in mutual position are regulated by the direction of the teeth. It is a well-known fact that in anthropoids the lower incisors usually occupy a vertical position while the upper ones are inclined forward. There can be overbite or edge-to-edge bite (cf. Weidenreich, 1937b). In the reconstructed *Sinanthropus* skull the upper incisors stand erect (the maxilla fragment—Maxilla No. III—used as a model), and the two distances in question are equal. In modern man there is great variability in the direction of the upper incisors and in the relative length of the two lines. There are cases in which the mandibular length exceeds the maxillar length as in anthropoids, or the reverse conditions may exist. This relative instability of the lower jaw is due to the easily discernible fact that the mandible is much less rigid in shape and proportions than is the maxilla. Concerning the human mandible I wrote in 1934: "The mandible apparently has various means for adjusting itself to the maxilla and thus coming to an occlusion: (1) the body can increase or decrease in length; (2) the entire jaw can be stretched or shortened by increase or decrease of the angle where ramus and body meet; (3) the front part can turn forward or backward by increase or decrease of

the inclination; (4) the alveolar process alone can shift its position; and (5) the teeth can be set in the jaw in an upright or oblique direction." This flexibility is also found in *Sinanthropus*. In anthropoids there seems to exist a greater tendency to fixation, probably due to the extraordinary development of the canines, which requires a much more intimate contact of the jaws for normal functioning.

2.   Height and Breadth

As the facial indices show (Table XXXIII), the upper face of *Sinanthropus* has the same proportions as that of modern man, the upper facial index measuring 52.1 while in modern man it varies from 49.0 to 57.4.   The *Sinanthropus* face is, therefore, relatively broad; the upper facial height totals 77 and the bizygomatic breadth 148.   In modern Eskimo the average height is 77 and the average breadth 145.   The total facial index of *Sinanthropus* amounts to 79.7, the average of modern man to 88, the values ranging from 74.0 to 94.0 in the latter case.   This measurement, too, shows the relative breadth of the *Sinanthropus* face.   Applying the usual terms to *Sinanthropus*, he should be classified as hypereuryprosop for the total face but only as mesen for the upper face.   To the same mesen group belong most of the Mongolian racial units, the Eskimo being recorded in Martin's list as having an index of 53.4.

3.   Nose, Orbita, Maxilla, and Palate.

The nasal index of *Sinanthropus* measures 57.2.   *Sinanthropus* must therefore be classified as chamaerrhine although he comes very close to the hyperchamaerrhine group.   In modern man the index ranges from 38.9 to 60.2 with an average of 50.0; in Martin's list the Tasmanian, Kaffir and Nubian show nearly the same average as *Sinanthropus*.   The index of the piriform aperture totals 90.8 in *Sinanthropus*.   The modern Australian varies from 82 to 130 in this index, the average of the Negro is 100, that of the European only 70.   The profile angle of the nasal roof amounts to 69° (FH as base; cf. no. A 8; Table XXXIII).   *Sinanthropus* thus falls within the range of modern man in which the individual variation varies from 43° to 76°; an angle of 69° is a little above the average of the Mongolian racial groups which range from 66.4° to 68.3°.   When the profile angle of the roof is measured with the nasion-prosthion line as base the result is 16°.   In modern man the individual values vary from 1° to 47°, the Mongolian racial groups from 16.1° to 19.5°.   By the first-mentioned method the angle is closer to the upper limit, by the second it is closer to the lower limit.   But in both cases, the Mongols show the same average.

The orbital index of *Sinanthropus* amounts to 81.9 when the maxillofrontale is taken as median landmark for the breadth, and 90 when the lacrimale is taken.   The orbit is, therefore, mesoconch or even hypsiconch.   This is somewhat surprising, for the first impression one has when looking at the face is that of a rather chamaeconch orbit.   This is apparently due to the heavy supraorbitals and the straight course of the supraorbital margin.   Nevertheless, the height which amounts to 36 mm. is considerable owing to the wide, downward curve of the inferior margin.   In modern man the index of the different racial groups ranges from 73.9 to 93.2 (with the maxillofrontale as median landmark); according to R. Martin, the male Kalmuck, Burmese, and Battak have the same index (81.8 and 81.9).   In the anthropoids the orbital index is much higher, the average totalling 101, but the chimpanzee shows lower values, the minimum ones dropping even to 76.   The width of the *Sinanthropus* orbit is 44 mm., which is within the range

of human variation but close to the upper mark, the individual minimum-maximum values ranging from 30 to 47 mm.

The interorbital index of *Sinanthropus* is 22.5. In the different racial groups of modern man the values range from 18.2 to 22.2; the *Sinanthropus* index is just beyond the upper end of this range. In R. Martin's list the European (Swiss) with an index of 22.2 comes closest to *Sinanthropus*. The angle of the orbital axes totals 52° in *Sinanthropus*. This is a little more than the greatest angle (51°) found by Adachi in Japanese. In Europeans the average is only 41.7°. The wide divergence of the axes is largely due to the great distance between the two optic foramina and the great interorbital breadth, as has been mentioned above.

Of the four walls of the *Sinanthropus* orbit only the superior one is longer than that of modern man. However, it is difficult to determine its anterior landmark. In modern man the supraorbital margin has a sharp-edged crest which descends from the usually deeply vaulted roof. But *Sinanthropus* has neither a crest nor a sharp edge; the roof is very slightly vaulted and the margin is a thick rounded structure. In measuring the length of the roof, the anterior terminus should be either the point projecting farthest on the anterior surface of the torus and in line with the orbital axis or the line along which the lower surface of the torus continues into the roof. In the first case the length of the roof amounts to 63.5 mm., in the second case to 57 mm. According to Adachi (1904), the average length of the roof in Japanese amounts to 51.8 mm. with a variation of 46 to 57 mm., and according to St. Oppenheim (1940), to 50.1 with a variation of 48.6 to 51.8 mm. in different races of modern man. It is obvious that in *Sinanthropus* the heavily developed supraorbitals contribute to the greater length of the orbital wall. This is apparent in the figures given by Keith (1927) for some of the Neanderthal skulls with heavy supraorbitals: Galilee 62 mm., Gibraltar 63 mm., La Chapelle and Rhodesian, each 65 mm.

The greater length of the roof is apparently also responsible for the greater capacity of the orbit when *Sinanthropus* is compared with modern man. It amounts to 74 cc. for the two orbits. Computed on the basis of Schultz's figures (1940) the average capacity of the two orbits of modern man totals only 46.7. In anthropoids there is, according to the same author, a wide variation ranging from 31 to 102 cc. The male gorilla, with its heavy supraorbitals and greatly protruding maxilla, has of course a larger orbit than has the female orang-utang.

Of the inclination angles of the *Sinanthropus* orbit only the vertical one falls beyond the range of human variation. It measures 111° (cf. Fig. 205) while the upper limit in modern man is 105° (ranging from 81° to 105°), according to St. Oppenheim (1940). In the anthropoids, according to the same author, the angle is much smaller ranging from 55° to 93°. The *Sinanthropus* angle exceeds that of modern man because of the heavy supraorbitals which push the upper terminus of the orbital tangent forward. On the other hand, the lower value of the angle in anthropoids, despite their well-developed supraorbitals, is due to their pronounced maxillar prognathism which pushes the lower terminus of the tangent much farther forward that it does in *Sinanthropus* or modern man. Since this prognathism is only slightly greater in *Sinanthropus* than in modern man the lower terminus of the tangent is comparable to that of modern man while the upper terminus is determined by the retention of the anthropoid features. The frontal inclination angle measures only 11° in *Sinanthropus* whereas the average of modern man is 17.5° with an individual range of 9° to 28°. In anthropoids the angle is 0° in chimpanzee and orang-utang, rising only in gorilla to 5°. The small angle indicates that in *Sinanthropus* the lateral border of the orbit has been pushed farther forward in relation to the medial one than is the rule in modern man; in other words, the malar region is more nearly in line with the nasal saddle, the

face appearing "flat." According to R. Martin's list, the frontal inclination angle of modern man is lowest in Mongolian racial groups, the average ranging from 14.2 in Japanese to 18° in Fuegians with an individual variation of 11° to 18° in the former group and 13° to 20° in the latter. The horizontal inclination angle amounts to 10° in *Sinanthropus*. This angle is the least characteristic of the three. The average of modern man is 12.6°, according to St. Oppenheim, with the Mongolian average very close to this figure. In anthropoids the angle totals 0° to 3° (chimpanzee).

The malar profile angle (cf. Fig. 205) of *Sinanthropus* is 106°. According to R. Martin's list, this angle varies in modern man from 108.8° in Buriats to 120.2° in Europeans (Swiss). Among the lowest values, aside from the Buriats, are those of the Kalmucks and the Telengets. In anthropoids the angle is much smaller, ranging from 67° to 110° after St. Oppenheim (1940). The reason for the major differences in the angle is the same as is the case with the vertical inclination angle of the orbit: the more the malar bone protrudes the smaller the angle, and conversely. In Mongols with their characteristic prominence of the cheek bone the angle is smaller than in other races. *Sinanthropus* with an angle of 106° falls well within the Mongolian group.

The nasomalar index should provide another means for estimating the degree of flatness of the face. The index totals 107.3 in *Sinanthropus*. In modern man it varies from 105.9 (Chinese) to 113.0 (Singhalese), according to R. Martin's list. However, this index is rather an indicator of flatness or elevation of the nasal bridge than of the prominence of the lateral region of the upper face. Since in *Sinanthropus* the bridge is relatively high the nasomalar index is not so low as that of the Chinese. Nevertheless, it is very close to that of the Mongolian racial groups which range from 105.9 to 106.6.

The maxillo-alveolar index of *Sinanthropus* is 107.6, which brings the skull into the dolichuranic group. The index of the racial groups of modern man ranges from 108.2 to 126.0; that of the anthropoids begins with an index of 52.1 and rises to 106. *Sinanthropus*, therefore, just fills the gap between the anthropoids and modern man. In other words, the alveolar arch is wider in span in *Sinanthropus* than in anthropoids but does not quite reach the width of the human arch. As the measurements of the maxillo-alveolar length and width reveal, *Sinanthropus*, in both cases, is very close to the upper limit of the individual variations of man. The lower index of *Sinanthropus* in comparison with that of modern man is, therefore, due to the fact that the alveolar arch is longer as well as narrower than in man.

The palatial index of *Sinanthropus* reveals the same conditions. This amounts to 75.1 indicating that the skull must be classified as leptostaphyline. In anthropoids the palatial index is much smaller; the individual maximum value is that of a male chimpanzee with an index of 62.5. The higher index of *Sinanthropus* is apparently due to its being wider as well as shorter than in anthropoids. The *Sinanthropus* height index amounts to 30.7. In modern man the individual indices range from 20.0 to 55 with an average of 33. An index similar to that of *Sinanthropus* may, therefore, be found among all racial groups. In anthropoids the index is much higher ranging from 40–55 with an average of 46. The high index is not due to the narrowness of the palate—the palate breadth at the level of the interstice between first and second molar is about the same in anthropoids and modern man—but to its greater height; the average in modern man is about 13, in *Sinanthropus* 12, in anthropoids 17.7. The considerable height in the case of the anthropoids is the result of the special development of the alveolar process, which, in its turn, is to a certain extent dependent upon the size and strength of the teeth.

V. CALVARIA AND FACE

The general relation between calvaria and face can be expressed by the longitudinal, transverse, and vertical cranio-facial indices. The longitudinal index represents the length of the face in proportion to the maximum length of the calvaria. This index amounts to 58 in *Sinanthropus* indicating that the distance from basion to prosthion is little more than half the distance from glabella to opisthocranion. In modern man the index is below 58, the average being close to 50, while in anthropoids it rises to over 100. The vertical cranio-facial index which shows the proportion between the height of the upper face and the total height of the calvaria amounts to 66.8 in *Sinanthropus*, to a little over 50 in modern man, and to almost 100 in anthropoids. The transverse cranio-facial index which shows the proportion between the bizygomatic breadth and the maximum breadth of the calvaria amounts to 105.7 in *Sinanthropus*, to about 93.8 in modern man, and 136 in anthropoids. All three indices indicate that in anthropoids the size of the face (length, height and breadth) in proportion to the size of the braincase (expressed by the corresponding dimensions) is much greater than in modern man, *Sinanthropus* ranking between the two groups but closer to man than to the great apes. This is due not only to the great dimensions of the face but still more so to the smallness of the braincase in anthropoids and the reverse condition in modern man. The extent to which the expansion of the braincase affects the size of the face is seen in the case of *Saimiri*. In the specimen depicted in Fig. 201 the longitudinal index totals 76, the vertical index 63, and the transverse index 109. *Saimiri* approaches the conditions of *Sinanthropus* much more than those of the anthropoids. The reason is obviously because it possesses a much larger brain. I shall take up this question again later.

The zygomaticofrontal index which in *Sinanthropus* totals only 64.7 against an average of 72.0 in modern man shows the narrowness of the frontal part of the calvaria in relation to the breadth of the face. Similar conditions are, however, found in modern man; certain Mongolian groups have, according to R. Martin's list, an index ranging from 66.2 to 68.7.

Other indices of the relation between calvaria and face can be disregarded since none of them contributes more to the elucidation of this relationship than those referred to. But there is still another index which is interesting because it tells something about the relation between the cranial capacity and the volume of at least part of the face. This is the cephalo-orbital index. Since the cranial capacity of the reconstructed *Sinanthropus* is 1015 cc. and that of the two orbits 74 cc. the index is 7.3. This value is much greater than that of modern man, in which the average of all the races totals 4.2; in anthropoids the index is 14.2. These differences are mainly due to the larger cranial capacity of man and *Sinanthropus* when compared with that of anthropoids, and much less to differences in volume of the orbit. In any case, it is impossible to judge the size of the eyeball from the size of the orbit (cf. Schultz, 1940 and Weidenreich, 1941b) which depends much more on the extension of the size of the superstructures of the braincase and the facial skeleton than on the size of the organ of vision.

The close correlation that exists between braincase and face can best be demonstrated when the measurements used for comparison of the two components of the skull are strictly confined to the braincase proper, and when we, therefore, disregard the superstructures which, despite their intimate connection with it, in reality belong to the face. The longitudinal craniofacial index discussed above gives only a general idea of the true conditions, for the glabella-opisthion length includes in *Sinanthropus*, and still more so in anthropoids, a strongly developed glabellar torus while its equivalent in modern man is negligible. The differences in this index, which are remarkably great (anthropoids: over 100; *Sinanthropus*: 58.8; modern man: 52), become, of course,

even greater when instead of the outer maximum length, the inner maximum length of the brain-case is correlated with the length of the face. When *Sinanthropus* Skull XI, the model of the reconstructed *Sinanthropus* skull, is used for the determination of the inner length (167 mm.) the longitudinal cranio-facial index of *Sinanthropus* rises to 70.4. In the European skull de-picted in Fig. 203 the index is 57.0, and in the gorilla skull it reaches the same figure. The shorter the inner length of the braincase the longer the face; or the smaller the brain the larger the face.

Since I have devoted a special study to the general significance of this problem (1941b) I am dealing with it here only in so far as *Sinanthropus* is concerned. The correlation can be demonstrated by using the metrical methods recommended in this paper. Although it might seem that to confine the testing of the correlation to only one length measurement would make it unreliable, the results, in principle, prove to be the same, even when the braincase is represented by a simplified diagram, the calvaria determined only by the main landmarks and the face indi-cated by the upper facial triangle, as depicted in Fig. 206. All measurements are related to the nasion-opisthion line equalling 100. The use of the outer outlines of the braincase instead of the inner ones will, of course, yield figures that are not so accurate as may be desired, but, by leaving out the glabella, at least a main source of inaccuracy in comparing the different groups will be avoided. Fig. 206 shows that the size of the face is in inverse ratio to that of the braincase. The greater the expansion of the latter the smaller the former, and vice versa. The three groups selected for this comparison and represented by their average measurements are anthropoids, *Sinanthropus*, and modern man. In the case of the facial triangle *Sinanthropus* has been re-placed by the male *Pithecanthropus* Skull IV. The size of the facial triangle of the reconstructed female *Sinanthropus* skull in relation to anthropoids and modern man can be gathered from Fig. 204. However, it must be remembered that in this figure the sides of the triangle are longer than they are in Fig. 206, since n-ba has been reduced to the length of n-o equalling 100 while in Fig. 206 n-ba itself equals 100.

When the area of the calvaria diagram is computed and expressed in proportion to that of the upper facial triangle the ratio amounts to 74 in anthropoids, to 37 in *Sinanthropus-Pith-canthropus*, and to 22 in modern man. In the reconstructed female *Sinanthropus* skull, the face of which is smaller, the ratio is 28. Fig. 202 and Table XXX show that the same conditions exist in the category of the platyrrhines. The greatest contrast in size of braincase and size of face are found in *Saimiri*, on the one hand, and male *Alouatta*, on the other, while *Cebus*, *Lago-thrix*, and *Ateles* occupy a medium position. *Saimiri* possesses the relatively largest braincase and the smallest face and male *Alouatta* has the relatively smallest braincase and the largest face. When the respective areas are computed their ratios are as follows: *Saimiri*, 40.0; *Cebus*, 58.7; *Lagothrix*, 64.3; male *Alouatta*, 112. Male *Alouatta* is the only platyrrhine in which, to conform with the size of the face, the nasion-basion line extends backward to such an extent that the occipital foramen turns backward (cf. Fig. 202).

It is particularly interesting that, even in individuals of modern man, the same correlation can be demonstrated between size of braincase and size of face. Hrdlička (1939) compared the measurements of calvaria and face of 25 micro-crania with a cranial capacity, ranging from 910 to 1050 cc. and an average of 996 cc., with those of 20 macro-crania with a cranial capacity, ranging from 1750 to 1915 cc. and an average of 1816 cc. He found the ratio: upper face module in relation to cranial module (Hrdlička speaks of "capacity" and not of cranial module) 67.7 in the micro-crania and 66.2 in the macro-crania; that is only a slight difference in favor of the

micro-crania, which may be regarded as negligible. Indeed, Hrdlička concludes: "The face as a whole retains, to a large extent, the same correlation with the external dimensions of the vault in both the micro- and macro-crania." However, the author made an important mistake. The upper face module on which he based his calculations includes only height and breadth, but not the length which should also have been included while the cranial module used for the calculations correctly includes all three dimensions. If the upper facial module is completed by adding the length, omitted by Hrdlička but recorded in his list, the ratio upper face module in relation to cranial module amounts to 101.7 in the micro-crania and to 97.6 in the macro-crania. In other words, in the micro-crania of modern man the three dimensions of the upper face are greater than the corresponding dimensions of the calvaria whereas they are smaller in the macro-crania. Hence, the larger the braincase the smaller the face, and vice versa, even within the same group (modern man).

If not micro-crania with an average capacity of 996 cc. but abnormal ones with an average capacity of only 326 cc. (cf. Table XXXIV) are compared with the average skull of modern man the differences between the size of the calvaria and the size of the face are still greater, although in those cases of microcephaly the face, like the body, shares in the general reduction of the skull. In the five skulls listed in Table XXXIV, the longitudinal cranio-facial index amounts to 71.4, and, when the inner skull length is taken instead of the outer one, even to 84.2 against 50 and 57, respectively, in normal-sized modern man.

VI. THE CRANIOGRAMS AND MID-SAGITTAL INDEX-DIAGRAMS

The metrical appearance of the *Sinanthropus* skull discussed in the preceding sections was illustrated by craniograms of the individual skulls and the reconstructed one. In this section I want to complete the picture by furnishing additional craniograms, particularly those which have been constructed according to Sarasin's directions, although I consider some of them to have only a limited value. Nevertheless, there may some day be need for all available data on the *Sinanthropus* material.

The craniograms of the *Sinanthropus* Skull III (Black's Skull of Locus E) have already been reproduced in Black's paper (1931; cf. also Fig. 181) and also the median sagittal craniogram of Skull II (Black's Skull of Locus D). I can therefore confine myself to the craniograms of the best-preserved Skulls X, XI, XII, and the reconstructed skull.

Of the sagittal craniograms (Figs. 207–210) the mid-sagittal ones do not differ from the craniograms depicted in Figs. 180 and 182–184, except for their orientation in the Frankfort Horizontal. The mid-orbital craniograms are of particular interest in so far as the orbital region is concerned (cf. Figs. 211, 212). In all the supraorbitals the glabellar torus overlaps, as is seen in the mid-sagittal craniogram. As is shown in Figs. 208 and 209, the supraorbitals of Skulls XI and XII are fairly well separated from the frontal scale by a wide and well-developed furrow which is, however, much less pronounced in Skull X (Fig. 207). Another noteworthy feature revealed by these diagrams is the flatness of the orbital roof and the rounded-off character of the supraorbital margin. The forehead itself appears more depressed in the mid-orbital diagrams than in the mid-sagittal ones; the more vaulted appearance of the latter is due partly to the presence of a crista sagittalis, partly to the frontal tuberosity that flattens toward the sides. The lateral orbital diagrams demonstrate how far laterally the supraorbitals extend; they appear to be special areas more or less separated from the outline of the malar region. In the corresponding diagram of modern man there is no such isolation (Fig. 212). Only in skulls with heavy

TABLE XXXIV

Linear Measurements (CM), Angles (CA) and Indices (CI) of Hypermicrocephalic Human Skulls

CM	Linear Measurements	Schütteln-dreyer ♂	M. Maehler ♀	Jena (Gött.) ♂	Paris ♀	Basuto ♀	Min.-Max.	Average	Modern Man (normal-sized)	Anthro-poids (average)
2	Horiz. projected length	141	126	133	120	—	126–141	130	184.3	—
8	Nasion-basion line	100	84	88	78	79	78–100	86	102.7	—
9	Nasion-opisthion line	126	112	119	103	102	102–126	112.4	135	127
10	Horiz. occip. length	26	19	21	27	—	19–27	23.2	56.0	17
13	Bregma position to n-o	40	37	37.5	37	39	37–40	38.1	33.2	47.2
13a	Vertex position to n-o	74	67	72	68	70	67–74	68.2	—	—
14	Lambda position to n-o	109	107	105.5	95	102	95–109	103.7	148.7	116.6
15	Inion position to n-o	135	122	128.5	120	120.5	120–135	125.2	169.5	}131
16	Opisthocranion position to n-o	135	122	126	120	120.5	120–135	124.7	185.6	
34	Basi-bregmat. height	91	81.5	84.5	77	86.5	77–91	84.1	134	—
36	Auricular height	66	67	71	61	—	61–71	66.2	113.5	—
44	Bregma height: n-o	58	56	56	57	63	56–63	58	107.7	—
45	Vertex height: n-o	72	66	69	69	77	66–77	70.6	124.6	—
46	Lambda height: n-o	62	55	62	60	64	55–64	60.6	94.6	—
47	Opisthocranion height: n-o	44	28	45	27.5	46	27.5–46	38.1	67.0	—
48	Inion height: n-o	44	19	28	27.5	46	19–46	32.9	36.8	—
74	Cranial capacity (in cc.)	365	285	360	280	340	285–365	326	1300	415
CA	**Angles**									
11	Frontal inclination	55°	56.5°	57°	57°	58°	55°–58°	56.7°	72.6°	52.5°
12	Occip. inclination	75°	84°	78°	82°	91°	75°–91°	82°	99°	83.1°
14	Angle of the cranial base	6°	8°	8°	6°	10°	6°–10°	7.6°	6°	10°
FA										
2	Nasion angle of the upper facial triangle	77°	74°	80°	75°	76°	74°–80°	76.4°	67°	100°
CI	**Indices**									
11	Bregma height II	45.8	50.0	47.0	55.3	61.6	45.8–61.6	51.9	78.5	46.1
12	Vertex height	57.1	59.0	58.0	67.0	75.3	57.1–75.3	69.3	91.0	54.0
13	Lambda height	49.1	49.1	52.1	58.3	62.6	49.1–62.6	54.2	69.1	44.7
14	Opisthocranion height	34.9	25.0	37.8	26.7	45.1	25.0–45.1	33.9	49.6	22.2
15	Inion height	34.9	16.9	23.5	26.7	45.1	16.9–45.1	29.4	27.3	42.0
16	Bregma position to n-o	31.8	33.1	31.5	35.9	38.2	31.5–38.2	34.1	24.2	35.3
16a	Vertex position to n-o	58.8	59.6	60.5	66.1	68.5	58.8–68.5	62.7	65.4	64.1
17	Lambda position to n-o	86.8	95.6	88.8	92.2	100.0	86.8–100.0	92.7	109.3	95.3
18	Occip. length I	18.5	15.1	15.8	22.5	—	15.1–22.5	18.0	30.6	12.7
19	Occip. length II	−7.0	−9.0	−5.8	−16.3	−20.5	−5.8−−20.5	−13.7	−21.8	−6.4
43	Nasion-basion length	79.3	75.0	74.0	75.6	77.4	74.0–79.5	76.3	75.3	83.8

superciliary arches such as are found in Australian aborigines (Fig. 211) can the zygomatic processes be indicated by an expansion of the upper end of the outlined malar region. In broad skulls of modern man the outlines of the temporal region as they appear in lateral orbital diagrams usually extend much farther forward than in narrow skulls (cf. Figs. 211 and 212).

The outlines of the occipital region exhibit in all *Sinanthropus* specimens a distinct prominence of the occipital torus; this prominence is also discernible in the mid-orbital diagram, indicating the considerable lateral extension of this structure.

There is nothing else that deserves particular mention. That all outlines of the craniograms have the form of a long-stretched oval while those of even dolichocranial modern skulls are more circular is of course a consequence of the lowness of the *Sinanthropus* skull. The special pattern of the outline of the temporal bone, as revealed in the lateral orbital craniograms of Figs. 208 and 209, and its difference from that of modern man have already been discussed in the chapter dealing with the separate bones (cf. especially Fig. 113).

It is of great interest to compare the sagittal craniograms of the two best-preserved *Homo soloensis* skulls (VI and XI) with that of *Sinanthropus*. Apart from the former being larger than the latter, there are some characteristic differences in details (cf. Figs. 217 and 218), particularly in the orbital and occipital regions. In contrast to the conditions in the *Sinanthropus* skulls (Figs. 207–210) the mid-orbital craniogram does not overlap the mid-sagittal one, indicating that the glabellar torus is heavier than the supraorbitals. Despite the strength of these structures they are much more closely connected with the forehead proper than they are in *Sinanthropus;* this is due not only to the course of the mid-sagittal contour which lacks the curvature between the glabellar torus and the squama proper but also to the continuity between the outlined temporal area and that of the zygomatic process as it appears in the lateral orbital craniogram. The occipital outlines indicate the strong development of the occipital torus and its far-reaching lateral extension.

The horizontal craniograms of the *Sinanthropus* Skulls X, XI, XII, and the reconstructed one (Figs. 212–216) show the following characteristic features: the far-lateral bulging of the supraorbitals; the pronounced postorbital constriction; the deep indentation of the porial plane at the porion; the salience of the contour of the mid-orbital plane in front of the lambdoid suture, indicating the angular torus (cf. particularly Figs. 213 and 215); and the bump of the occiput (cf. Figs. 213 and 214). As for the general form of the skull, it is remarkable that, in contrast to conditions in modern man in whom the outlines of the four planes behind and before the porion are almost superimposed on each other, these outlines are fairly well separated in *Sinanthropus*, the transverse distance between the left and the right outlines of the parietal plane being by far the smallest and that of the mid-orbital plane the greatest. This condition is merely the expression of the fact, repeatedly mentioned above, that the parietal region of the *Sinanthropus* calvaria recedes above the base while it bulges beyond it in modern man.

The characteristic features exhibited by the coronal craniograms of *Sinanthropus* Skulls X, XI, XII (Figs. 182–184) and the reconstructed skull (Fig. 191) have already been discussed. Therefore, once more we must emphasize the form of the outline of the interporial plane with its broad base and gradually receding contour, the prominence of the sagittal crest, and the parasagittal depression on either side. In the posterior coronale the triangular character of the outline is still more pronounced, since the line cuts through the projecting angular torus and the obelion is considerably lower than the bregma. Of the depicted *Homo soloensis* skulls only Skull XI (Fig. 198) shows similar, though less pronounced, conditions whereas Skull VI (Fig. 197) is more like a Neanderthal skull. On the other hand, the outlines of the interporial and posterior coronale of the *Pithecanthropus* Skull IV (Fig. 196) form almost perfect triangles, exaggerated by the strong prominence of the supramastoid crests at the base and the knob-like thickenings of the sagittal crest at the apex.

As was explained above, the plotting of the mid-sagittal craniogram is the most comprehensive means of demonstrating the characteristic form of a calvaria, particularly when different types are to be compared. The diagrams shown in Fig. 219 represent the outlines from nasion

to opisthion in natural size of an anthropoid (female gorilla), Pithecanthropus (Skull II), Sinanthropus (Skull III), modern hyperdolichocranial man (Australian aborigine with a length-breadth index of 66.4), and modern hyperbrachycranial man (European, Austrian, with a length-breadth index of 89.2). The craniograms are first oriented in the Frankfort Horizontal and then superimposed at the porion. They show that in form and expansion of the braincase Sinanthropus occupies a middle place between the anthropoids and modern man with Pithecanthropus coming very close to Sinanthropus. They illustrate, furthermore, that there is a characteristic change in the form which apparently accompanies the expansion of the braincase. If the Frankfort Horizontal is taken as base and the porion is fixed the braincase expands in upward, backward and downward directions, particularly upward. However, if the nasion-opisthion line is taken as base-line and the craniograms are superimposed at the middle point of the line the general relation between the different types remains the same but certain peculiarities become more distinct. In Fig. 220 I attempted to illustrate by means of craniograms the minimum (A) and maximum (B) extension of the braincase of four Sinanthropus specimens, five Homo soloensis, six Neanderthalians, and sixteen modern man, representing various races and contrasting forms and sizes. The diagram of the minimum values shows that the higher hominid groups, despite their close approximation to Sinanthropus, differ from him principally in the greater height of the braincase. Even in cases in which the calvaria of modern man is a good deal shorter than that of Sinanthropus while their cranial capacities are equal, the height of the braincase of modern man far exceeds that of Sinanthropus. The diagram of maximum values (B), when compared with the diagram of minimum values, reveals a fact, scarcely recognized, that the amplitude of the variation in size increases with the process of the hominid organization; in other words, the difference between minimum and maximum values in the expansion of the braincase is greater in modern man than it is in Sinanthropus. The diagrams also show that the porion, too, changes its position in relation to the nasion-opisthion line; as direct measurements prove (see above), it shifts upward and slightly forward during the evolutionary stages, particularly in the last stages.

Figure 221 illustrates the differences in form and size of calvaria and face of Sinanthropus (reconstructed skull) and a dolichocranial modern European of Nordic race, as seen in median sagittal craniograms. When the nasion and the nasion-opisthion line are taken as base, the change in the position of the main landmarks gives a fair indication of the direction and extent of expansion of the braincase and the reduction of the face. These changes are marked by arrows. The bregma has moved upward and forward, that is, the entire squama of the frontal bone has risen by turning about a transverse axis laid through the nasion. The lambda has moved upward and backward but much less than has the bregma and with a backward rather than an upward trend; at the same time, the opisthion has moved forward, so that the movement of the occipital bone seems to be more complicated than that of the frontal bone since it has turned about a transverse axis laid through the original opisthocranion (op; i). At this landmark still another change has taken place: the angle between the upper and lower scales the apex of which is represented by the opisthocranion has increased and the original sharp bend of the occipital bone has become a wide curve. In other words, the occipital bone has turned its opisthion terminus inward and its lambda terminus outward; in fact, the entire bone seems to have stretched considerably. As a result of this change, the opisthocranion and inion which coincide in Sinanthropus are seen to have separated, the opisthocranion having moved upward and the inion downward. Neither the frontal nor the occipital bones have increased appreciably in length; the change they have undergone in relation to the base-line can best be described as

an opening at the vertex of the skull. The vertex itself has moved upward and only slightly forward. But the parietal bone which fills the gap between bregma and lambda has increased considerably in length in order to close the widened gap.

The tendency of the pre-occipital part of the calvaria to move upward and forward, as indicated by the shift of bregma and vertex, also involves the base proper, represented by the nasion-basion line, and the location of the porion and klition. In Fig. 221 the changes in position of these landmarks are demonstrated. Basion, porion, and klition take the same upward and forward direction as did the vertex and bregma but to a lesser extent. The morphological expression of this change is the development of a pronounced deflection having its apex at the klition. This causes the occipital foramen to change its direction so that it faces downward or even forward, instead of backward.

Due to these changes the braincase does not expand equally in all directions but tends to retain and even to accentuate the basic shape of the brain-stem with its characteristic midbrain curvature. It is this cerebral region that moves farther upward toward the vertex as the curvature becomes narrower while the cerebellar and medullar regions move downward (cf. also Fig. 203).

The reduction of the face has been treated in discussing the relation of the calvaria to the face. Fig. 221 shows that with the shortening of the nasion-basion line the prosthion and the incision move backward and upward while the nasospinale and the gnathion are very little affected. This differentiation results in a relative prominence of the nasal spine and the chin, as shown above.

The course of the transformation of the hominid skull can be seen very clearly in a mid-sagittal index-diagram (Fig. 222) in which the outline of the braincase is replaced by the main landmarks—nasion, basion, vertex, lambda, opisthocranion (inion) and opisthion—and the distances between the individual landmarks and the basal nasion-opisthion line are indicated by their indices, if this line is equal to 100 (cf. Table XXVII). The hominid types represented in this diagram are: *Pithecanthropus* Skull II, average *Sinanthropus* (Table XXI), average *Homo soloensis* (Table XXIII), average Neanderthalians (Table XXV), and average modern man (twenty representatives of various races). This purely metrical diagram, unlike that of Fig. 221, is not limited to one individual of each type but embraces all of them. It reveals the same conditions as were found in the craniograms, but in more definite form, and demonstrates particularly that the principle of construction of the calvariae is identical in all hominid forms and that their existing divergences are those of size only. It also emphasizes the fact that *Pithecanthropus*, *Sinanthropus*, and *Homo soloensis*, despite their differences in size, are very closely related while Neanderthal is a more advanced type already approaching modern man in its development.

The diagram in Fig. 223 completes the picture in that it proves that the hominid pattern derives from that of the anthropoids, the differences in pattern being only those of size. Even morphological differences in the superstructures of the braincase are entirely dependent upon this factor. In the diagram of the anthropoids the inion is found to be high above the opisthocranion and very close to the lambda; in *Sinanthropus* these two landmarks coincide; in modern man their positions are reversed the inion having shifted downward and the opisthocranion having approached the lambda. The expansion of the braincase and reduction of the bulk of the cervical muscles are responsible for this transformation.

The specific form of the braincase, however, is not merely a matter of size. As I have shown above, the anthropoid-hominid pattern is found only in these groups of primates and in

all catarrhines. In the platyrrhine group the braincase appears to be set obliquely on the base with a distinctly backward tilt (Fig. 223). Whether the braincase is relatively small as in the male *Alouatta* or large as in *Saimiri* the platyrrhine pattern is always retained.

An impressive example of the tenacity of the anthropoid-hominid pattern is found in microcranial human skulls whose cranial capacity does not exceed 400 cc. In Table XXXIV are listed the linear measurements, angles, and indices of five microcranial skulls with a capacity ranging from 285 to 365 cc. All represent adult individuals, none under twenty years of age; four are Europeans and one is a South African Negro; two are males, three females. For further details the reader is referred to my paper on the rôle of the brain (1941b). The figures in Table XXXIV prove that the braincase is not a copy in miniature of the braincase of normal-sized man but shows a clear tendency to revert to a form similar to the original anthropoid pattern. The index-diagram in Fig. 224 was constructed in the same manner as the diagrams of Figs. 222 and 223 and show the mutual positions of the main landmarks in relation to the nasion-opisthion line. Except for the vertex which is disproportionately higher than the other landmarks, indicating the advanced human character of the type despite the smallness of the skull, the frontal bone recedes to a surprising degree; the frontal inclination angle (no. A 11) measures only 56.4° against 72° in modern man and 52.5° in anthropoids, and the bregma height index (no. I 11) measures 51.9 against 78.5 and 46.1. The inion, too, occupies an intermediate position. In modern man the inion is located 45 per cent below the opisthocranion; in anthropoids it is 47.5 per cent above the opisthocranion; and in microcephalics 12 per cent below the opisthocranion. Thus, in microcranial human skulls the nuchal plane of the occipital bone occupies a much larger area in proportion to the entire bone than it does in modern man, although the high point of the anthropoids is by no means attained. These facts are evidence that it is really the radical expansion of the brain which is responsible for the morphological transformation of the hominid braincase, starting from an anthropoid-like base.

I have already pointed out that sagittal and coronal craniograms can tell us a great deal about the characteristics of the calvaria whereas the horizontal diagram can tell relatively little. Fig. 225, A and B, show the minimum and maximum range of the four hominid groups, represented by *Pithecanthropus*, *Sinanthropus*, Neanderthal man, and modern man. The diagrams are superimposed at their centers, that is, at the middle points of the mid-sagittal and mid-transverse lines. As in the median sagittal diagrams (Fig. 220; A, B) the variation between the two extreme contours is much greater in the more advanced evolutionary stages than in the more primitive ones. Except for the orbital and postorbital regions there are no essential differences in form in the four groups.

The diagrams show, in addition, the oft-mentioned fact that the interporial breadth is decidedly smaller in modern man than in *Pithecanthropus* and *Sinanthropus*. The frontal region of the three primitive groups is characterized by the development of the supraorbitals. Their prominence in the anterior and lateral directions dominates the picture. The diagrams show, however, that the pronounced postorbital constrictions are not due merely to their bulkiness but to the narrowness of the frontal squama as well. This region is much broader in Neanderthal and modern man than it is in the *Pithecanthropus* and *Sinanthropus* groups.

D. The Architectonic Structure of the Skull

I. THE FRAMEWORK

The preceding section dealt with the general form of the *Sinanthropus* skull and the properties which distinguish it from recent man. The *Sinanthropus* skull is considerably lower although in length as well as breadth the absolute proportions are the same in principle (with due allowance for variations in either type). Another characteristic feature which is combined with the lowness is that the *Sinanthropus* calvaria is broadest at its base. The breadth between the auriculare exceeds all possible breadths taken within the same interporial coronal plane; in other words, the breadth gradually decreases toward the vertex while in modern man the breadth at the base is smaller than any breadth further upward or, at best, equal to it.

In a section drawn through the skull in the interporial coronal plane the *Sinanthropus* craniogram appears as a low triangle with broad base and curved sides while that of the skull of recent man—if a hyperbrachycephalic type is chosen as example—presents a high, wide and slightly oblated circle (Fig. 226). *Pithecanthropus* shows the same pattern as *Sinanthropus*. The differences appear all the more pronounced in mid-sagittal section through the skulls (Fig. 227). In *Sinanthropus* as in *Pithecanthropus* the greatest length (glabella-opisthocranion) coincides with the glabella-inion line while the calva is low. In modern man—again if a hyperbrachycephalic type is taken—the greatest length falls far above the inion while the calva is high. Whereas in the first case the entire skull is flattened to such an extent that the glabella-inion plane is the real base from which the calva rises, in modern man it appears as a largely inflated globe with no distinct base at all in the geometrical sense.

The glabella-inion plane which thus forms the architectonic base of the *Sinanthropus* calvaria is characterized by two special formations, one occupying the front and the other the rear. The frontal formation consists of the two supraorbital tori and the single glabellar torus, which together might be designated as suprafacial or frontal torus. The rear formation consists of the occipital torus and similar structures connected with it. Both tori systems represent superstructures (cf. Weidenreich, 1940b; 1941b). They are formations having no intransic connection with the braincase proper which lodges and protects the brain, but are rather additional constructions for the purpose of strengthening those parts which are subjected to special strain, or of enlarging the surface of the calvaria by providing adequate space for muscular attachment.

In all types of fossil hominids with heavy jaws and strong dentition, the suprafacials are well developed. They constitute reinforcements of the cranial framework and serve as buttresses against the force of mastication which particularly affects the front part due to the greater projection of the jaws. If you look over the literature you would come to quite different conclusions; for orang-utangs have no suprafacials, despite their far-protruding muzzles, heavy jaws and strong dentition. This objection, however, falls short of the point. For, in reality, the orang-utang has at least typical supraorbitals in the dynamic sense. They differ, it is true, from those of gorilla and chimpanzee since they do not project at so sharp an angle; yet they present semi-annular structures embedded within the supraorbital margin itself and are composed of very dense bony substance. This arrangement is probably due to the rounding and shortening of the braincase—characteristic of orang-utang.

The suprafacial torus of great apes receives masticatory pressure through two transferring systems, the "crista canina" and the "crista alveolo-zygomatica" (Goerke, 1904) which arise on either side of the alveolar process from the canine and molar regions and run upward toward

the nasofrontal and frontozygomatic junctions where they merge with the torus. According to Strasser (1913), the conditions are in principle the same as in man. Strasser distinguishes **two** pillars; one, the frontal pillar is represented by the frontal processes of maxilla and nasal bone; the other, the zygomatic pillar, is located within the lateral frame of the orbit.

In contrast to the suprafacials, the significance of the posterior reinforcement of the basal framework of the early human skull has so far completely escaped attention. It is well-known that all skulls belonging to early stages show an occipital torus but this formation was merely considered in connection with the cervical muscles and consequently its development was thought to be entirely dependent upon the bulkiness of these muscles. In an earlier publication (1940b) I have demonstrated that what is called torus occipitalis is only the hindmost portion of a ring system of protuberances beginning at the level of the articulary tubercle of the temporal bone and extending almost continuously to include the whole post-otic region of the skull (Fig. 228). Its individual components appear more or less independent; this, apparently, is also the reason why they have special designations such as crista supramastoidea, torus angularis ossis parietalis, and torus occipitalis. Crista supramastoidea and torus occipitalis may still occur in recent man, although considerably reduced in extent and strength, but the torus angularis which links them in *Sinanthropus* and appears as such a characteristic feature has disappeared so completely that the original continuity of the ring structure is not even suggested.

There is no doubt, of course, but that the occipital torus serves for the attachment of the cervical muscles. But this relation cannot be held primarily and exclusively responsible for its formation. The only visible morphological effect these muscles produce is the bilateral impression on the upper area of the nuchal plane, the demarcations of which go under the names of linea nuchae superior and crista occipitalis externa, the latter separating the two impressions within the mid-line (cf. Figs. 229 and 230). In the female *Sinanthropus* Skull XI and in the juvenile Skull III not only the impressions, their demarcating lines, and the internuchal crests are completely missing but the entire nuchal plane is distinctly convex, though there is a well developed torus which is no less strong than in skulls with pronounced muscle markings. The opinion still recently advanced by McCown and Keith (1939) who regard the occipital torus as "the wave of bone which precedes the expanding insertion of the semispinalis capitis and also the trapezius . . ." does not find any confirmation from the morphological facts presented by *Sinanthropus* and *Pithecanthropus*. The relation between torus and cervical muscles, inserted or arising at the occiput or within its range, is exactly the same as that between the suprafacials and the temporal muscle. The superficial anterior portion of this muscle and its fascia arise from the lateral corner of the supraorbitals but they certainly did not produce the protuberances themselves.

The occipital torus is only a part of the semi-circular system which surrounds the posterior moiety of the skull base from one articular tubercle to the other. This system is an intrinsic structural element of the post-otic portion of the calvaria and serves as reinforcement for the base of the cranial framework (Fig. 228). In this capacity the system is complemented in the front by the superfacial tori. The only gap that exists between the pre-otic and post-otic ring systems coincides with the post-orbital constriction and the temporal fossa. But even this seemingly weak spot in the architectonic structure of the skull base fits into the framework: the constriction is bridged over by the zygomatic arch which arises from the anterior extremity of the post-otic ring and joins the posterior extremity of the pre-otic ring by intercalation of the frontosphenoidal process of the zygomatic bone and the zygomatic arch.

One other formation serves as a means to fill the gap in the system to a certain extent. In the description of the interior surface of the parietal and temporal bones, attention has been drawn to the "crista Sylvii" which rises like a spur from the inner surface of the sphenoidal angle of the parietal bone and joins the parietal margin of the lesser wing of the sphenoid (Fig. 234 A-C) connecting the cranial wall with the central parts of the base. A second transverse system which connects the anterior extremity of the posterior reinforcing ring with the center of the base is represented by the pyramid itself. As was shown above, the pyramid is a rather solid element of the *Sinanthropus* calvaria. However, the real architectonic center of the base, placed within the body of the basi-occipitale, is not preserved. Even if it had, it would not have differed from that of modern man, so its significance as such a center is unquestionable. Figures 231–232 represent an attempt to illustrate these conditions by diagrams. They show that the pre-otic and post-otic semicircular units work as a kind of hoop which holds the skull casque together and secures it against compression by a stiffening system composed of transverse beams.

Two longitudinal systems are combined with this horizontal basal system. The most striking one, peculiar to *Sinanthropus* as well as *Pithecanthropus*, is represented by the sagittal crest (Fig. 231). This crest, also present in the Rhodesian Skull and certain types of modern man, is very pronounced in all of the *Sinanthropus* specimens and especially developed in the vertex region between bregma and obelion. It begins behind the ophryon and tends to widen at the bregma into a cross-like prominence, a peculiarity present in the *Sinanthropus* skulls but especially pronounced in *Pithecanthropus* Skulls I and II. The sagittal crest is not at all an upturning of the sagittal margins of the parietal bones as may appear at first glance but consists rather of a keel-like protuberance accentuated by the parasagittal depressions of the adjacent surfaces of the parietal bones. Nor is it homologous to or a relic of the mid-sagittal crest of male anthropoids as has been suggested by certain authors who discussed its nature. For the temporal lines, the equivalent of the sagittal crest in anthropoids, are well developed in both *Sinanthropus* and *Pithecanthropus* but run a good deal farther laterally and below the mid-line and median crest. In *Pithecanthropus* Skull IV, the heaviest prehominid skull which has ever been found, the crest is composed of a row of more or less isolated knobs having no contact with the temporal line or any attachment of the temporal muscle (Figs. 229 and 230, csg): the torus angularis (tp) represents the hindmost extremity of the temporal line. In *Pithecanthropus* Skull IV, it is true, the exact course of this line cannot be traced on account of the crushed conditions of the parietal bones but there can be no doubt that the line runs quite a distance laterally from the mid-sagittal knobs. This independence of the mid-sagittal crest from any muscular marking corresponds completely with the conditions of the occipital and suprafacial tori and corroborates the interpretation of the sagittal crest as a purely architectonic structure.

Such an explanation is furthermore substantiated by a fact which so far has escaped notice. Both *Sinanthropus* and *Pithecanthropus* possess a well developed crista frontalis on the cerebral side of the skull. This fades out just where the sagittal crest originates on the outside. The same conditions are found in the occipital bone. Of the two sagittal arms of the cruciate eminence the inferior one is a distinctly projecting crest as implied by the name "internal occipital crest." The superior arm, however, is called "sulcus sagittalis" though no groove is carved on the even surface of the bone as suggested by this designation, but it is rather a broad elevation which lodges the sulcus. From the architectonic viewpoint not the sulcus but the elevation is the essential structure; it continues downward beyond the crucial eminence into the internal occipital crest and, in upward direction, it fades out completely in the obelion region. In other

words, where the sagittal crest terminates on the outside an internal crest develops and extends down to the occipital foramen. The dura mater is attached to each one of these ridges.

The sagittal reinforcing-system of the vault which starts from the foramen caecum and runs out at the posterior rim of the occipital foramen forms a circle by means of a basal portion which unites the anterior and posterior terminations just defined; this basal portion begins with the crista galli, continues into the body of the basioccipitale and meets the posterior extremity of the upper sagittal system by dividing into two branches which embrace the occipital foramen. The basal portion seems to be interrupted only by the lamina cribrosa but is considerably widened and strengthened just behind that region (cf. Fig. 232), so that the body of the sphenoid appears as the architectonic center of the base. The lateral parts of the occipital bones are strong girders which, through the condyles, receive and distribute the pressure passing from the head to trunk and vice versa.

There are two transverse systems: the anterior consists of the Sylvian crest with the rim of the lesser wing of the sphenoid as its medial continuation; the posterior is the pyramid. Both link the basal center and the post-otic portion of the ring system. These systems, characteristic of *Sinanthropus* and *Pithecanthropus*, have disappeared more or less in modern man. This is especially true of the basal ring system with its most striking features, the frontal, the angular and occipital tori. Its only remainders are represented by the superciliary ridge; the zygomatic process, the zygomatic arch, the supramastoid crest and the external occipital protuberance. All these structures are but faint reminiscences of the heavy, primary ones. The sagittal system is somewhat different; the sagittal crest has been retained in certain races of modern mankind though not in the form of a true thickening of the bone along the mid-line but, rather indirectly, as the result of flattening of the adjacent parts. The crests on the inner side maintained their original character; but they are mere ridges for the attachment of the dura mater. The basal portion of the sagittal system, too, still functions but it is impossible to compare it with the primary conditions, for this portion is not preserved in any of the prehominid skulls. The transverse system (Sylvian crest and pyramid) also persists but is considerably reduced in development and strength.

II. THE MASSIVENESS OF THE BONES

There is no doubt but that the reduction of the reinforcing-system of the calvaria accompanies the transformation of the human skull in the course of evolution. Before entering into any discussion of this problem, however, it must be remembered that the skulls of *Sinanthropus* and *Pithecanthropus* differ from that of modern man not only in the special development of this system but also with respect to the thickness and heaviness of the bones participating in the construction of calvaria and face. It is a well-known fact, and one often reported, that the skull caps of fossil hominids appear considerably thicker than those of modern man. But as yet, so far as I was able to ascertain, no one has provided actual figures or deemed the entire phenomenon worth special consideration.

In order to furnish an idea of the thickness of the braincase of *Sinanthropus* and *Pithecanthropus* skulls casts have been cut through at the ophryon-inion plane as illustrated in Figure 234 (A-C): *A* represents *Sinanthropus* Skull III, *B Sinanthropus* Skull XII and *C Pithecanthropus* Skull II. The pictures reveal the extraordinary thickness of the bones, particularly that of torus occipitalis and torus angularis (tp); they also indicate the sagittal system, as far as it is represented by the crista frontalis and the internal occipital crest (Fig. 234, C). In addition, Figures

235 and 236 show mid-sagittal and interporial coronal sections through *Sinanthropus* and *Pithecanthropus* skulls, which permit one to see at a glance the thickness of the bones. However, some of the depicted skulls have injuries on the outer surface which diminish the measurements within their range, and this must be taken into account.

The absolute figures derived in this way do not mean much unless compared with those of modern man. Such measurements were taken by Todd (1924), and others are listed in R. Martin's textbook (1928). But these authors chose landmarks in part incommensurable with those of primitive types including, for instance, the thickness of the frontal bone taken at the glabella or that of the occiput taken at the external occipital protuberance. Furthermore, it must be remembered that the accuracy of measurements may be considerably decreased by quite incidental interferences such as the landmark falling on an impressio in one case and on a jugum in the other. The thickness of the human parietal bone measured at the vertex does not correspond to that of gorilla if the height of the sagittal crest is included in the latter case. R. Martin records a thickness of 15 mm. for the occipital bone of modern man measured at the external protuberance. In *Sinanthropus* the average thickness taken at the center of the occipital torus amounts to 17 mm. However, as I have shown previously (1940b) and also discussed above, the two structures in question are not identical, and thus the thickness of the bones at this landmark cannot be compared.

Table XXXV

Thickness of the Cranial Bones of Sinanthropus and Pithecanthropus

Kind of Cranial Bone	Special Locality	Sinanthropus Skulls											Pithecanthropus Skulls			
		I	II	III	V	VI	VII	VIII*	IX	X	XI	XII	I°	II	III*	IV
Os frontale	1. Glabella	—	20.0	23.0	—	—	—	—	—	23.0	18.7	22.0	—	—	—	—
	2. Torus supra-orbitalis:															
	a. Medial port.	—	14.2	13.5	—	—	—	—	—	12.6	14.0	17.0	—	—	—	—
	b. Middle port.	—	14.0	11.5	—	—	—	—	—	13.0	14.0	16.0	—	12.0	—	—
	3. Center of the squama	13.0	10.0	10.0	—	(9.5)	—	—	(7.1)	7.0	11.0	7.0	7.0	9.0	—	—
	4. Facies temp.	—	6.5	4.8	—	4.6	—	—	(5.6)	(5.8)	4.6	5.5	4.0	3.5	—	—
Os parietale	1. Near the bregma	—	9.0	9.6	—	(9.9)	—	—	—	7.5	7.0	9.7	9.0	9.0	10.0	5.5(?)
	2. Tuberosity	5.0?	11.0	11.0	—	11.2	—	—	—	12.5	16.0	9.0	9.0	12.5	10.0	11.5
	3. Angulus mastoid.	14.0	13.5	17.2	14.0	—	17.4	—	—	14.0	13.5	14.5	—	14.0	9.5(?)	14.0
Os occipitale	1. Center of the occipit. planum	—	(10.7)	10.0	(7.0)	—	—	(5.0)	—	10.0	9.0	9.0	—	13.0	7.0	13.5
	2. Center of the occipit. torus	—	—	20.4	(12.3)	—	—	7.1	—	15.0	12.0	15.0	15.0	20.4	—	21.5
	3. Fossa cerebellaris	—	—	6.8	4.5	—	—	3.8	—	(5.0)	2.8	2.5	—	5.0	—	5.0
Os temporale	1. Center of the squama	—	10.0	9.3	10.0	7.7	—	—	—	(5.2)	6.0	7.0	—	8.0	—	7.0

* Measurements followed by question mark are uncertain because of fracture or compression of the bone; such within brackets are taken next to the landmarks concerned; skulls marked by an asterisk refer to juvenile individuals; ° figures after H. Weinert (1928). All of the measurements of *Sinanthropus* are revised; they differ in part from those given in the paper on the "Torus occipitalis" (1940, Tables I and II.)

TABLE XXXVI

Thickness of Cranial Bones (Minimum-Maximum Values and Averages) of Adult Prehominids,
Adult Neanderthal Skulls and Adult Modern Man (in mm.)

Kind of Bone	Special Locality	Sinanthropus		Pithecanthropus		Neanderthal Group After Authors and Casts*		Modern Man After R. Martin's Textbook (1932)	
		Min.-Max.	Aver.	Min.-Max.	Aver.	Min.-Max.	Aver.	Min.-Max.	Aver.
Os frontale	Center of the squama	7.0–13.0	9.3	7.0–9.0	8.0	4.0–8.0	6.8	5.8–6.3	6.05
	Facies tempor.	4.6–6.5	5.3	3.5–4.0	3.75	3.0–6.5	4.5	1.0–2.0	1.5
Os parietale	Near the bregma	7.0–10.0	8.8	5.5(?)–9.0	8.4(?)	5.0–9.0	7.7	5.5	5.5
	Tuberosity	5.0(?)–16.0	10.8	9.0–12.5	11.0	6.0–11.0	9.0	2.0–5.0	3.5
	Angulus mastoideus	13.5–17.4	14.8	14	14.0	4.0–9.0	7.25	4.5–5.2	4.85
Os occipitale	Center of the occipital planum	7.0–10.7	9.2	13.0–13.5	13.25	7.0–9.0	7.7	6.0–8.0	7.0
	Center of the occipital torus	12.0–20.4	17.0	15.0–21.5	19.0	10.0–15.0	12.3	15.0	15.0
	Fossa cerebell.	2.5–6.8	4.3	5.0	5.0	1.2–4.0	2.7	1.0–1.8	1.4
Os temporale	Center of the squama	5.2–10.0	8.0	7.0–8.0	7.5	4.0–9.0	6.5	1.3–2.5	1.9
Average index		—	9.7	—	10.0		7.2		5.2

* For figures cf. Table on pages 90 and 91 in F. Weidenreich, Der Schädelfund von Weimar-Ehringsdorf, 1928.

In Table XXXV the thickness of the four bones which constitute the wall of the braincase (the frontal, parietal, occipital and temporal bones) is recorded for all available specimens of *Sinanthropus* and *Pithecanthropus*. The frontal bone is measured at five different landmarks, the parietal and the occipital at three and the temporal at one landmark. Of these twelve measurements nine were selected for comparison with the corresponding measurements of modern man and do not conflict with the principles just set forth. Table XXXVI contains the minimum-maximum values as well as the average of the nine measurements of: (1) *Sinanthropus-Pithecanthropus;* (2) several skulls of the Neanderthal group, according to the list given in my publication on the Weimar-Ehringsdorf skull (1928, pp. 90/91); and (3) of modern man after R. Martin (1928). Finally, a general average thickness-index was computed from the averages of each of the nine measurements. This index is 10.0 in *Pithecanthropus*, 9.7 in *Sinanthropus*, 7.2 in Neanderthal man and 5.2 in modern man. In other words, the cranial wall is about half as thick in modern man as it is in *Pithecanthropus* and *Sinanthropus* while that of the Neanderthal man is intermediate. If the thickness is related to the capacity of the skull—a calculation mathematically not correct because it combines linear measurements with cubic—the thickness-capacity indices are about 1.11; 0.97; 0.54; and 0.39 for the four groups listed. How great the differences are between prehominids and modern man may be gathered from Figure 238A which presents a horizontal section cut through the calvaria of a male Australian aborigine slightly above the ophryon-inion plane. When compared with an approximate section through the *Sinanthropus* and *Pithecanthropus* skulls as depicted in Figure 234 (A-C) the decrease in thickness is apparent.

The twelve measurements of Table XXXV and the nine of Table XXXVI involve landmarks which fall on the reinforcing-systems of the skull as well as those which are completely outside of it. As the figures demonstrate, the prehominid skulls are considerably thicker than

those of modern man, regardless of the location of the landmarks. But there are certain areas which, though they cannot be considered to be within the reinforcing-systems, prove to be much thicker than the average. This is particularly true of the parietal tuberosity of *Sinanthropus* and *Pithecanthropus* (cf. Fig. 237 A-D). In modern man this region is much thinner than in the other groups which, in turn, seems to indicate that the reduction of the cranial wall in the course of human evolution is correlated with the expansion of the braincase.

It is a well-known fact that skulls with extraordinarily thick cranial walls occasionally are found in modern man under quite normal conditions. Such a case is illustrated in Figure 238 B which represents a prehistoric Chinese skull (province Shansi, Tou Chi Tai), where the face and greater part of the frontal bone are not preserved. Thick cranial walls are not necessarily a pathological condition caused by Paget's disease or similar disturbances. But so far as I was able to ascertain, the thickness in such cases is chiefly due to an enlargement of the diploë and not to a thickening of the external or internal table. In *Sinanthropus*, however, all three constituents of the bone take equal part in the thickening, the two tables slightly more than the diploë (cf. Figs. 19 and 20). That this holds good also for *Pithecanthropus* Skull IV is proven by Figure 243. There is only one remarkable exception to this rule; it concerns the supraorbitals which, as breakages (Figs. 6, 12, 54, 60) and skiagrams (Fig. 223, A-D) show, consist chiefly of diploë or, more correctly, of loose cancellous tissue.

The massiveness of the prehominid calvaria, contrary to the conditions in modern man, is all the more surprising since there is no real equivalent to it in anthropoids. If the superstructures and the air sinuses are disregarded and only the braincase proper is taken into account neither gorilla, nor orang-utang, nor chimpanzee match the prehominid skull in massiveness. None of their cranial bones which form the wall is thicker than those of modern man; rather they are thinner. This becomes evident when a horizontal section through the gorilla skull is compared with a corresponding section through the skull of *Sinanthropus*, *Pithecanthropus* and modern man (cf. Figs. 234, A-C; 238, C). The gorilla depicted in Figure 238C is a female but even in the strongest male individuals the great difference in thickness is evident (cf. the skiagrams of the four male and three female gorilla skulls in Harris, 1926, Fig. 5, p. 170).

III. PNEUMATIZATION

As I have already pointed out above, the supraorbitals proper of *Sinanthropus* contain no air sinuses. The frontal sinus is very small and even when larger than usual as in Skull III (Fig. 228, D) is strictly confined to the interorbital or glabellar region and does not extend laterally into the roof of the orbit. The skiagrams of the three skulls (reproduced in Figure 228, A-C) do not indicate the presence of any sinuses; but sinuses are displayed in the drawings taken from the base of the skulls where they are exposed by the breaks (cf. Figs. 60, 72, 84; sf). In Figures 72 and 84 the sinuses appear as large anterior ethmoidal cells rather than as frontal sinuses. In Skull III (Fig. 228, D) there is a large sinus on either side of the midline but in this case also it does not extend further laterally than to the medial orbital walls where it continues into the orbital roof. Its greatest breadth is 24.5 mm. and the greatest length (depth) 14–15 mm.

These conditions in the frontal sinus of *Sinanthropus* contrast strikingly with those of *Pithecanthropus*. It is true, that the glabellar and supraorbital regions are preserved only in one case (Skull I) but the sinus is very large, its greatest breadth being 26 to 30 mm. and its greatest length 24 mm. according to Dubois (1924) and Weinert (1928). In consequence of this great breadth the sinus extends in a lateral direction into the roof of the orbit. Although the

difference between *Sinanthropus* and *Pithecanthropus* may not be considered significant with regard to the development of a frontal sinus in *Sinanthropus* Skull III, I believe, it is.   It seems to me as if the tendency in pneumatization were less pronounced in *Sinanthropus* than in *Pithecanthropus*.   This view is supported not only by the fact that in three out of the four *Sinanthropus* skulls available for such comparison the frontal sinuses are very poorly developed but also by one other piece of evidence which points to the same direction.   In *Pithecanthropus* Skull IV a large sinus occupies the base of the pterygoid process while in *Sinanthropus* Skulls II and XI there is no indication of such a formation although a sufficiently large part of the pterygoid base has been preserved.

I am far from being inclined to consider the presence or absence of frontal sinuses decisive criteria for the classification of types as Weinert (1926) and, just recently, his pupil Bauermeister (1940) declared.   In two previous publications (1924a and 1941b) I was able to prove that air sinuses considered from static and dynamic viewpoints are not "active" but "passive" formations or, in other words, represent "void rooms" not essential for the transmission of stress and strain in the architectonic structure of the skull.   Consequently, they develop where a large incongruity exists between the frameworks of two adjacent systems of organs; for instance, the frontal sinuses occupy the space between the anterior pole of the braincase, the roofs of the orbits and the nasal tunnel.   It follows from this point of view that the sinus is the larger the greater the distances and incongruities between these three constituents of the cranium.   In gorilla, for instance, where the orbits are located considerably anterior to the pole of the braincase and where heavy, far-protruding supraorbitals have developed the frontal sinus is enormous while it is almost completely wanting in orang-utang where the braincase is short and rounded, the orbits hardly project before the braincase, and the "supraorbitals" are set within the rims of the orbits themselves.   The incongruity described is the reason that large dogs such as wolfhounds and setters exhibit large frontal sinuses while sinuses are completely wanting in dwarfs like the Pekinese, King Charles spaniels, etc.   In dwarf types with relatively large and protruding braincase and short and receding face there is no space left and no architectonic need for the development of frontal sinuses (cf. Figs. 269 and 271).

The opinion often advanced that the large size of bones containing air sinuses is but a consequence of their inflation by the air blown, as it were, into the spaces of their cancellous tissue is based on erroneous supposition.   The frontal sinus is, ontogenetically, not formed because penetrating air forces apart the compacta layers of bone: as Sitsen (1934) has proved, the spaces of the diploë become wider long before the mucous membrane of the nasal cavity grows out into them.

One other factor, however, must be taken into account.   Air is only one of the materials which is used to fill "void rooms."   In long bones where the medullary canal is statically and dynamically an equivalent of sinuses the rooms are filled with marrow or fat, and the same is true of all spongy parts of the skeleton where a more or less loose trabecular system suffices for static and dynamic needs.   In mammals air is used only in bones where the air supply is close at hand.   But since air is not an element which can be distributed in such small portions as fat or marrow because it has to be stowed in special sacs, its use as filling material is restricted to those cells which do not drop below a certain size.   Where a dense trabecular system within the spongy substance is required for reasons far beyond our knowledge, there are either no air sinuses or their establishment is confined to certain places.   The correctness of these conclusions may be inferred from the manner in which the mastoid portion of the human and simian temporal

bones is pneumatized. From Wittmaack's (1918) observations as well as from L. Hofmann's (1926/27) it follows that the smaller size of cells is not determined by their contents; they may be filled with marrow or air, the choice of material depending entirely on individual or "constitutional" factors.

Thus, the reason, on the one hand, for a great variation and, on the other, for a certain steadiness in the development and extent of the air sinuses, particularly of the frontal sinus (cf. Sitsen, 1934), becomes clear. In gorilla and chimpanzee the frontal sinus is extraordinarily large while it is small or lacking in orang-utang. There is no sphenoidal sinus with direct nasal communication in orang-utang but this air sinus is provided by a recess of the maxillary sinus. In the same anthropoids the maxillary sinus extends medially into the palate and the sphenoid sinus laterally into the pterygoid process. The pigmy chimpanzee (*Pan paniscus*) has no frontal sinus while the normal-sized animal (*Pan schweinfurthi*) has one (cf. Coolidge, 1933; Weidenreich, 1940b). The cellulae ethmoidales of gorilla, chimpanzee and orang-utang, except for one or two posteriores, are merged, according to Seydel (1891), into a large posterior recess of the frontal sinus. In gorilla the canalis naso-lacrimalis of the maxillary sinus is enlarged to a wide cyst-like recess. Independent cellulae ethmoidales in larger numbers have developed only in man. In this respect he differs not only from the anthropoids but also from all the catarrhine and platyrrhine apes in which these cells are either completely lacking or restricted to one or two cells, the spaces they occupied being taken over by the frontal or maxillary sinus. A great variability exists in man in regard to the size and development of the frontal sinus. Sitsen (1931) who studied the variation in different races by means of skiagrams found very large and very small sinuses in all races. Yet there are other equally definite statements according to which racial differences do exist. Turner (1901) is cited as having asserted that in 30.4 per cent of Australian aborigines and 37 per cent of Melanesians the frontal sinus is lacking. Troitzky (1928) claims that he found a frontal sinus in only three of 22 skulls of Buriats and these sinuses were not larger than 1–2 cc. According to the same author, the sinus is lacking in 12 per cent of Russian skulls. As to the dimensions of the sinus in man, the height varies from 20.8 to 40.0 mm., the breadth from 10 to 37.5 mm. (for one side) and the depth from 15 to 20 mm., according to Weinert (1926) and R. Martin (1928).

It is not without special interest that in all of the skulls of the Neanderthal group the air sinuses wherever they have been noticed or measured are rather large, as is evident from Table XXXVII. *Sinanthropus* with his small frontal sinuses which appear as anterior ethmoidal cells rather than as true frontal sinuses occupies a singular position among fossil hominids and, undoubtedly, approaches orang-utang closer than gorilla or chimpanzee in this feature. Although it may seem superfluous to stress this fact again, I cannot tacitly disregard the persistence with which Weinert—and recently his pupil Bauermeister (1940)—hold to the claim that the conditions of the frontal sinus prove a closer relationship between man and chimpanzee than between man and other apes. The frontal sinus is such a variable formation and dependent on such a number of different factors that it certainly cannot be used in constructing phylogenetic lines. The single fact that dwarf types of dogs and chimpanzee have no sinuses while they reach extraordinary dimensions in large types of the same animals (see above) is sufficient to overrule any claim for phylogenetic significance (cf. also Schultz, 1936).

As for the other air sinuses, the body of the spenoid is preserved neither in *Sinanthropus* nor in *Pithecanthropus*. But the sphenoid sinus must have been well developed in the latter; for, as already mentioned, *Pithecanthropus* Skull IV displays a large sinus within the base of the

TABLE XXXVII

Dimensions of the Frontal Sinus (in mm.)

Specimen	Breadth	Height (Vert. Dim.)	Depth (Sagitt. Dim.)	Author
Sinanthropus Skull III	max. 24.5	—	14–15	Black, Weidenreich
Sinanthropus Skull X	max. 17	—	11	
Sinanthropus Skull XI	max. 8	—	7	Weidenreich
Sinanthropus Skull XII	max. 20	—	4	
Pithecanthropus Skull I	max. 26–30	—	24	Dubois, Weinert
Homo soloensis	vast in all dimensions			Weidenreich
Neanderthal	30–37	—	—	Schwalbe
Spy II	35	—	14–16	Fraipont and Lohest
La Chapelle-aux-Saints	vast in all dimensions			Boule
Le Moustier	vast in all dimensions			Weinert
La Quina	40	32	16	H. Martin
Saccopastore	vast in all dimensions			S. Sergi
Ehringsdorf	37	22	15	Weidenreich
Krapina C	29	—	12	S. Hofman
Galilee	"extending over the inner part of the orbital roof"			Keith
Recent Man	20–37.5	20.8–40	16–20	Brege, Mihalkovics, R. Martin

preserved pterygoid process. In *Sinanthropus* there is no sinus within the base of the pterygoid process, a fact which, of course, does not exclude the presence of a sinus in the body of the sphenoid but, in any case, indicates that, even if present, the sinus failed to expand to the same extent as in *Pithecanthropus*. A sphenoidal sinus extending laterally to the pterygoid process also existed in the Ehringsdorf and Galilee Skulls (Keith, 1927; Weidenreich, 1928). It is perhaps not purely accidental that widely expanded sphenoidal sinuses occur in *Pithecanthropus* as well as in those skulls of the Neanderthal group which also agree in the enormous development of the frontal sinus while *Sinanthropus* distinctly differs from them all in this respect.

All we know of the maxillary sinus of *Sinanthropus* is its broad, lateral expansion into the zygomatic bone: yet the sinus does not penetrate the palate nor does it engulf the nasolacrimal canal as it does in gorilla. In *Pithecanthropus* Skull IV maxilla and palate are preserved and the maxillary sinus exposed from above. At the time I studied the specimen the matrix had not been completely removed from the cavity, nevertheless I gained the impression that the sinus extended further medially toward the palate than in *Sinanthropus* and modern man. Nothing is known of these conditions in the skulls of the Neanderthal group. The Rhodesian Skull would be of special interest in this respect, but as far as I know, no skiagram of the skull has been published.

Although the pneumatization of the temporal bone of modern man has been studied by numerous authors, very little is known of fossil man. Even in cases in which the temporal bones are preserved no skiagrams or descriptions of the arrangement and extension of the pneumatic cells have been given. Davidson Black (1931, Pl. X) reproduced the skiagram of the left temporal bone of *Sinanthropus* Skull III together with one of modern man: "in order to show the peculiarly restricted character of the temporal pneumatization in the former." According to that author "no air cells extend from the mastoid region in *Sinanthropus* above the line of the supramastoid crest; nor are any such cells to be observed extending between the bony

tables in the digastric region in this form." On the other hand, Black stresses the "considerable medial extension of pneumatization that occurs within the medial mastoid crest of *Sinanthropus*," which, however, is not revealed in the reproduced skiagram.

Since the skiagram of the left temporal bone (of Skull III) depicted by Black was not taken in exact standard orientation (norma lateralis of the bone), a new skiagram of the same side is given in Figure 239 (B) together with that of the right side (Fig. 239, A). Furthermore, Figures 240–242 represent skiagrams of all the available temporal bones of *Sinanthropus*. Figures 240 (A, B) are those of Skull XI; Figure 241 (A) is that of Skull X and B that of Skull XII; finally Figure 242 is that of Skull V. The figures show that Black's statement that the air cells did not extend above the line of the supramastoid crest and behind the mastoid process proper cannot be considered as generally valid for *Sinanthropus*. In Skull V (Fig. 242) the cells undoubtedly extend far above the supramastoid crest and backward to the occipitomastoid suture. As to the limit of upward extension, it can be stated that the cells reach the lower margin of the squamous suture; this is also evident in Skull III if the skiagram is taken in the correct position of the skull. Toward the rear the cells, or at least some of them, spread over the entire mastoid portion (cf. 240 A, B; 241 B). The forward expansion seems to be more restricted, but in some cases (Figs. 240 A, B; 241 B; 242) the cells extend up to the articular tubercle. The individual cells are all fairly large; this applies particularly to the anterior, superior and posterior groups. This description and division of the cells, however, refers only to lateral aspects of the temporal bone, almost exclusively used when studying pneumatization on skiagrams. But the picture is somewhat different when the bone is examined on skiagrams taken from above and below. The fact that the *Sinanthropus* skulls show individual differences in abundance and size of the cells is already evident from a comparison of Skull III (Fig. 239 A, B) and Skull V (Fig. 242). But it becomes all the more apparent in skiagrams which represent the pyramid in vertical or basal views. Skull III (Fig. 228, D), thus presented, displays very poor pneumatization while in Skull XI (Fig. 228, B), particularly on the left side, the cells fill the entire pyramid to the apex and extend well backward to the occipitomastoid suture.

Any comparison of the pneumatization of the temporal bone of modern man meets with difficulty both because of great variability and the complete absence of any reliable statistics on average conditions or racial variations. But so far as the facts reported in the literature permit a conclusion in this regard, it is safe to state that pneumatization to an extent such as observed in *Sinanthropus* Skull V (Fig. 242) does not occur in modern man, even in cases which can be described as "extremely abundant ones." Mayer (1930) so describes a pneumatization which comes close to that of *Sinanthropus* Skull XI (left side; compare Fig. 240, B and Fig. 87, p. 101, in Mayer's handbook). The author gives the following description of the skiagram: "The cells extend forward up to the anterior root of the zygomatic arch, backward to the occipitomastoid suture. In upward direction the posterior cells reach high up into the squama. The entire pyramid, including the apex, has undergone a thorough pneumatization." Siebenmann (1898) studied the pneumatization of the human temporal bone on sections and on corroded preparations, the cells being filled with metal. He found that the horizontal cells which roof the external acoustic meatus rarely extend into the root of the zygomatic arch or upward beyond the supramastoid crest, and he considers the extension of the cells to the rear of the occipitomastoid suture also as exceptional.

As to the skulls of the Neanderthal group, the only temporal bone examined in regard to pneumatic cells is—as far as I was able to ascertain—the skull fragment C of Krapina. But

S. Hofman's (1933) skiagram fails to reveal very much of the cells except the fact that the pneumatization is rather poor and certainly less developed than the average of modern man.

The pneumatization in anthropoids is rather abundant (cf. L. Hofmann, 1926/27). It extends over the entire temporal bone upward to the outer margin of the squamous suture; forward to the sphenotemporal suture and into the zygomatic arch; backward into the occipital bone itself; in other words, the entire squama and mastoid portion are largely inflated by cells which occupy the whole space between the outer and inner compacta layers of the bone. Figure 243 shows these conditions in a female gorilla. Compared with the air sinuses and their partitions in other cranial bones the individual pneumatic cells are very small and do not exceed those of *Sinanthropus*. Unfortunately, no skiagram is as yet available of *Pithecanthropus* Skull IV. But since the fossilization of this specimen is rather far advanced not much can be expected from such a skiagram. Yet, judging from the abundant pneumatization of the frontal and sphenoid bones of this hominid and the bulkiness of the entire pyramid (cf. Fig. 244), the assumption is justified that the degree of pneumatization of the temporal bone may have exceeded that of *Sinanthropus*.

IV. THE REDUCTION OF MASSIVENESS IN THE COURSE OF HUMAN EVOLUTION

In the first paragraph of this chapter dealing with the reinforcing-systems of the calvaria it was pointed out that these systems undergo continuous reduction, so that very few of them are left in modern man. The reduction of the framework is closely correlated with a reduction of the entire cranial wall and appears merely as a part of this process. Its degree can be imagined when it is realized that in modern man the cranial wall is only half as thick as that of *Sinanthropus* or *Pithecanthropus*.

This reduction is not confined to the cranial wall but affects the base also as well as the facial skeleton. That the jaws and teeth underwent a constant decrease in size and strength, if an anthropoid-like type be taken as the supposed ancestor of man, is a fact long known and generally acknowledged. But it has almost completely escaped attention that in reality all the bones of the skull participate in this process, regardless of their relation to teeth or muscular apparatus. The reduction not only concerns the size but also affects the substance of the bone. In the preceding paragraphs in which the individual skeletal parts have been described certain phenomena which indicate this reduction have been mentioned repeatedly. Of those bones which form the base of the braincase the sphenoid and the temporal bones are particularly illustrative. In regard to the latter the reader is referred to Figures 125–129 which represent the pyramid and tympanic of gorilla, orang-utang, *Sinanthropus* and modern man and give a good idea of the changes in size, form and topographic relations these parts have undergone during evolution. The basic alteration that apparently determined all others is the decrease in size. One may object that such an assumption would imply an original hominid type whose pyramid may have matched those of a male gorilla in size. That such types actually existed is proven by *Pithecanthropus* Skull IV with its enormously developed pyramid (Fig. 244). In the specimen illustrated the left pyramid is crushed but the right one is intact, except for a negligible posterior part of its base. It is much larger than the pyramid of any male gorilla and far exceeds that of modern man (cf. Figs. 244 and 130). A comparison of Figures 125 and 127, sketched also in Figure 129, reveals the differences in length and breadth of the pyramid and the changes in its position connected therewith. The apex of the pyramid which originally overlapped the basisphenoid has retracted to such an extent that a broad and irregularly bordered perforation on the base (fora-

men lacerum) resulted (cf. Figs. 121–123). Simultaneously the pyramid shrank from a big and largely extended element at the floor of the cerebral fossa to a frail and morphologically insignificant one.

A similar retraction took place in the sphenoid angle of the parietal bone and the greater wing of the sphenoid. As already described, the cerebral surface of the sphenoid angle in *Sinanthropus* as well as in *Pithecanthropus* runs out into a broad, high, spur-like elevation (Sylvian crest) which continues into the lesser wing of the sphenoid, so that the sharply overlapping edge which separates the anterior cerebral fossa from the middle fossa extends laterally up to the parietal region of the cranial wall (Figs. 234 A, C; 27; 95; 98; csy). This conspicuous feature has practically disappeared in modern man although occasionally a more or less marked elevation is reminiscent of the original conditions (Fig. 130, csy).

The reduction of the greater wing of the sphenoid is manifested in an increase in width of the superior and inferior orbital fissures which takes place chiefly at the expense of the skeletal parts. It was shown above that in *Sinanthropus* Skulls III and XII the length of the superior fissure—indicated by the distance of the medial extremity of the sphenofrontal suture and the lateral border of the root of the lesser wing—is not much greater than the horizontal diameter of the optic foramen (Figs. 84, fos; and Black, 1931, Pl. XII, Skull III, left side). The tapering of the anterior extremity of the lower fissure as preserved in Skull XII (Figs. 79 and 84, foi), and the size of the orbital facies of the greater wing which extends considerably below the level of the Frankfort plane (op. cit.) indicate that the fissure was formerly a narrow cleft opening directly downward and not laterally into the infratemporal fossa as it does in wide fissures. For the rest it is sufficient to refer to the description of the sphenoid of *Sinanthropus* given above.

So far nothing is known about the variation in size of the upper fissure of modern man. In anthropoids Török (1881) has already called attention to the fact that, particularly in gorilla, the fissure appears as a more or less rounded perforation not much larger than the optic foramen. More information is available on the variation of form and size in the lower fissure of modern man. Tanzi (1892) who made investigations to determine whether or not a morphological difference exists between the skulls of normal and insane individuals found great variability in length as well as width, regardless of race, with minimum and maximum values relatively rare. Recent observations by Fenner (1939), carried out on Australian aborigines, agree with Tanzi's findings, as this author records 8–13 per cent very narrow fissures and 3–16 per cent very wide ones while the remainder are of medium width. In cases in which the fissure shows a tendency to widen, the anterior extremity is affected first and occasionally expands into a wide circular dilation more or less independently of the fissure proper (cf. Fig. 245, A; foi). In the gorilla the lower fissure represents, at the lateral corner of the orbital floor, a narrow slit which opens downward into the infratemporal fossa (cf. Fig. 245, C). In chimpanzee and orang-utang the conditions are somewhat different; the lower fissure appears as a canal rather than as a slit in the floor. This canal emerges from the oval foramen, runs forward and laterally beneath the orbital floor and communicates upward with the orbit and downward with the infratemporal fossa, but only the upward communication strictly corresponds to the lower fissure of man. The variation in length and size is rather slight in gorilla, but much more pronounced in chimpanzee and orang-utang.

There is no evidence that the width or narrowness of the fissures or their termination in a special dilation, as in the case of the lower one, has any bearing on the admission of nerves or vessels which pass from the cerebral fossa through the openings into the orbit or from the orbit into the infratemporal fossa. Even the shortest and narrowest fissure found in modern man

apparently provides sufficient space for that purpose. On the other hand, the entire lower fissure is closed, as positively stated by Forster (1904), by a "fast fibrous membrane" which, according to Groyer (1903), contains bundles of smooth muscle fibers representing the "musculus orbitalis or Muelleri." Thus, the reason for the differences in size must be sought in the skeletal parts and, as both upper and lower fissures are affected—although not always simultaneously—, it is the variability in the size of the greater wing which is responsible for the recorded alterations.

The fossil human material available so far is rather scanty. In only a few cases are the parts of the orbit under discussion preserved and even so, the majority of authors overlooked the conditions in question or failed to describe them. In addition, the skulls are photographed in such a way that the entire interior of the orbits is overshadowed. This is the case, for instance, in the Rhodesian Skull. The original, however, reveals that in either orbit the upper fissure is restricted to a small rounded slit of about the size of the optic foramen and the lower fissure is merely represented by a narrow cleft which retains its width up to the anterior extremity (Fig. 245, D). There is very little doubt but that the conditions in *Sinanthropus* were the same as in the Rhodesian Skull and thus very similar to those which are characteristic of the gorilla (Fig. 245, C).

The great width of the two orbital fissures as they occur in modern man must be considered as an indication of an increasing tendency to reduce the original massiveness on the part of the cranial bones. Shortness and narrowness of the fissures, therefore, are signs of primitiveness, length and breadth those of more advanced stages. Fenner's figures on the occurrence of extremely narrow and extremely wide lower fissures in Australian aborigines, it is true, do not render much support to such a view, as each of these categories have been found in about the same percentage. Krogman (1932), however, arrived at quite different results. According to him, there is a much greater percentage of linear or narrow lower fissures in Australian skulls than recorded by Fenner. Krogman states that 43 per cent of males and 63 per cent of females possess narrow fissures, while only 20 and 9 per cent, respectively, have extremely wide ones. Whether this discrepancy is due to diverging opinions as to what should be considered narrow and what wide or whether it is due to other factors, I am unable to decide. Yet, after examining a large number of skulls of diverse races, I arrived at the conclusion that narrow and wide upper and lower fissures occur in all races of modern mankind. But there is good evidence that skulls with a heavy structure in general have smaller fissures than lightly and fraitly built skulls. In Australian and Melanesian skulls the fissures certainly are generally smaller than in skulls of Malayans or dwarf races. Osman Hill (1941), for instance, notes in his study on the skulls of Veddahs that the "typical skull is slightly built with comparatively thin cranial bones" and with regard to the lower fissure he states that it is "generally wide throughout." In Figure 245, A and B, two extremes found in the skull collection of the American Museum of Natural History are reproduced. *A* is the lightly built skull of a male Bengali with extremely wide upper and lower fissures but without any indication of special atrophies. *B* is the heavily built skull of a male New Britain in which the upper fissure is reduced to a short and narrow opening and the lower fissure likewise to a narrow slit. The first case is an example of a "closed" orbit and the second that of an "open" one.

That the reduction of the greater wing of the sphenoid is not confined to the height of the wing but involves the entire bone is evident from cross sections through the wing illustrated in Figure 134. Compared with *Sinanthropus* the greater wing in modern man has shrunk to almost two thirds of its original thickness. An additional example is found in the zygomatic bone. As

a horizontal section through the frontosphenoidal process of this bone (Fig. 166) reveals, that of *Sinanthropus* (F) is much thicker than any of the four depicted specimens of modern man (C, D, G, H), regardless of race.

It is not necessary to supply special evidence that the same process affects the upper and lower jaws and the dentition. In a previous publication dealing with the dentition of *Sinanthropus* and that of modern man (1937, C) I arrived at the following conclusions: "When compared with *Sinanthropus* the teeth of recent man have undergone a very characteristic reduction. This reduction involves not only the size of the crowns and roots but apparently also a specific transformation of the entire pattern. . . ." "The teeth of the Neanderthal group approach much closer those of recent man than those of *Sinanthropus*, the reduction in that group having already advanced to a considerable extent. . . ." The reduction of the hominid dentition in the course of evolution as demonstrated by the three phases *Sinanthropus*—Neanderthal man— recent man cannot be considered an isolated process confined to the teeth but a consequence of the transformation of the entire skull. The reduction of the lower front teeth, including the canines, particularly that of their roots, leads to a reduction of the alveolar process and, consequently, to the projection of the basal part of the mandible which results in the formation of the chin. A similar transformation took place in the upper teeth. The reduction of the alveolar process led to the development of the nasal spine and to a characteristic shrinking of the entire maxilla which results in "hollow cheeks."

Reduction in size does not mean a decrease in dimension only but also a diminution of the bony substance itself. The mandible of modern man compared with that of *Sinanthropus* is not only shorter, narrower and lower but also considerably thinner in body as well as in ramus. The same is true of the maxilla. The walls bordering the maxillary sinus are thin in both *Sinanthropus* and modern man when they are compared with other cranial bones but they are much thinner in modern man than in *Sinanthropus*. In this instance the conditions are similar to those of the wall of the fossa cerebellaris (cf. Table XXXVI).

V. CAUSES AND CORRELATIONS

If follows from all these facts that massiveness of the bones of the braincase as well as of the face characterizes the skull of primitive hominids; and that this heavy construction has been subjected to a continuous reduction during evolution. The answer to the question, why did such an alteration take place, is: The reduction is a consequence of the gradually increasing expansion of the brain and the case accommodating it. In a recent paper (1941b) I was able to show that certain phenomena and typical differences in the appearance of anthropoid and human skulls can easily be explained by the effect this factor has on the architectonic structure of the skull. The expansion of the braincase necessarily leads to a change in form. Since the globular form is the most adequate for lodging the greatest possible mass within the least possible room the braincase shows an increasing tendency to assume such a form the more the brain expands. In the introductory remarks discussing the architectonic structure of the skull evidence was given, on the basis of comparative views of the skull contours drawn in two major planes (cf. Figs. 226 and 227), as to the extent of this transformation in the stages leading from *Pithecanthropus-Sinanthropus* to modern man. The immediate consequence of this alteration in shape is the gradual disappearance of the basal and longitudinal reinforcing-systems which seem perfectly adapted to a low calvaria with a flattened base (cf. Figs. 231 and 232) but will loose their significance the more the calvaria approaches the globular form.

I earlier called attention to the fact that the big superstructures (sagittal and nuchal crests, strong postorbital processes and large frontal sinuses) characterizing the skull of large dogs and equivalent to a certain extent to the reinforcing-systems of primitive hominids, disappear completely in dwarf dogs where a relatively large brain is forced to occupy those parts of the calvaria which remain far beyond its range in large dogs. It can also be demonstrated that cranial sutures which never close in dwarf dogs close very early in large types, and that the cranial bones are considerably thinner in dwarf dogs than in larger ones—a fact of special interest for the problem under discussion. The reason for all these differences is that the relatively large brain of dwarfs requires a large space within the small calvaria, and secondly that the braincase has, therefore, assured a more globular form. The transformation of the human skull in the course of phylogenetic evolution follows the same morphogenetic rules. Only the conditioning factors are different: In dwarf dogs the brain is relatively large in proportion to the size of skull and body. But in man the brain is really enlarged as a consequence of the general trend of human evolution (cf. Figs. 269 and 271).

With the diminution and final disappearance of the reinforcing-systems of the calvaria the entire wall of the human skull becomes thinner, and the cranial sutures occlude in a much more advanced stage of life, as has been set forth in my previous paper (1941b). In the same publication I also advanced the opinion that the persistence of the metopic suture—a relatively frequent occurrence in modern man but a rather rare one in anthropoids—must also be taken as a sign of the growing general tendency to widen the braincase. Disappearance of the Sylvian crest, shortening and shrinkage of the pyramid, and formation of the foramen lacerum must be interpreted in the same way, as an expression of the particular expansion of the middle cerebral fossa. The "open orbit" and the attenuation of the greater wing of the sphenoid are apparently the result of the same process.

As to the effect upon the facial skeleton proper, I have shown (1941b) that there is a close correlation between form and size of braincase and form and size of facial bones. "The enlargement of the braincase results in an extensive reduction of the face. This manifests itself not only in shortening of the face but also in its lowering. . . . Consequently, the palate and dental arch become short and wide instead of being long and narrow as in the type. The teeth are also affected by the alteration. The size of crowns and roots is greatly diminished and, in extreme cases of dwarfism, not only are premolars and molars reduced in number but their pattern also have undergone a remarkable simplification consisting in the loss of the cingulum and even of certain cusps. The reduction of the entire masticatory apparatus, in close connection with the enlargement of the braincase, fundamentally alters their mechanical correlations." The passage cited refers only to dogs but it can be applied without essential changes to the transformation undergone by the human skull during the evolution which led from the *Pithecanthropus-Sinanthropus* stage to that of modern man.

The shrinking of the frontal tori and the reduction of the facial skeleton underneath do not keep pace with one another in all cases. It often happens that the frontal bone retains its heavy character while the upper part of the face has become lighter and frailer. As a result of this disharmony the glabellar region and the supraorbitals continue to protrude whereas the nasal bridge and the lateral frame of the orbit have shrunk. This is a very common feature in Australian and Melanesian skulls. The development of a frontosphenoidal notch and a "processus marginalis" is the consequence of this disharmony (cf. Fig. 167).

As already described, the loss of massiveness which involves the facial bones must be regarded as only a part of the general reduction of the skull. At first glance such a statement seems to infer a contradiction. In the case of the calvaria the loss of massiveness is interpreted as the result of an expansion and, in the case of the face, as that of a reduction. Yet there is no real contradiction: the reduction of the facial skeleton involves the entire building material while the expansion of the braincase makes use of the building material available, and since the static and dynamic conditions undergo a radical change at the same time there is no need for the retention of the original massiveness. The loss of massiveness of the cranial and facial bones, therefore, can be explained as a direct result of the enlargement of the brain. The problem is: Why are early hominids fitted with those massive cranial bones the thickness of which is not proportionate to the size of the skull? I have already pointed out that in this respect hominids differ not only from the anthropoids but also from all lower primates. Differences in thickness of the cranial wall occur also among the latter groups. As shown in my previous publication (1941b), in all cases small species with relatively large brains and braincases have thinner walls than large species with relatively small brains and braincases. But in none of the latter category does the massiveness attain such a degree as in hominids. The wall of the anthropoid calvaria appears very thick in some places, even thicker than that of the hominids. Their thickness, however, is of quite another kind. It is not a general one but restricted to certain regions. When I discussed the problem of pneumatization I pointed out that the great apes owe the thickness of the cranial walls to an inflation with air while in primitive hominids spongy substance serves as building material of the enlarged bones. This difference seems all the less intelligible because great apes possess particularly bulky muscles which cannot well have been surpassed by those of primitive hominids. In addition, augmentation of the muscular mass leads only to enlargement of the surface of the bone but not to thickening and density of the bony substance itself (cf. Weidenreich, 1922). The development of the sagittal and nuchal crests in adult males of gorilla and organ-utang illustrates this kind of correlation. The extensive pneumatization of the anthropoid skull, therefore, cannot be regarded as an equivalent of the massiveness of the hominid bones, all the less since pneumatization occurs in *Sinanthropus* and *Pithecanthropus* in addition to the massiveness of their bones and remains confined to certain regions as in anthropoids while the massiveness involves the entire skull.

Taking all these facts into consideration, there is no doubt but that the massiveness of the cranial bones of early hominids constitutes a particular character by which the hominids are distinguished from all the anthropoids. This view is further substantiated by the fact that the massiveness is not confined to the skull but seems to involve all skeletal parts. Unfortunately, very few of these bones are available and, with the exception of a small fragment of the atlas of *Sinanthropus*, no other element of the spine is preserved. Limb bones consist merely of seven fragmentary femora and one humerus if the fragments of clavicle and os lunatum are omitted. As to *Pithecanthropus*, the Trinil femur must be disregarded and so must the four femurs of unknown origin which were found later and attributed to *Pithecanthropus* by Dubois, for their classification is doubtful.

However, despite their fragmentary character the limb bones of *Sinanthropus* yield sufficient evidence to support of the fact that the same conditions found in the skull have existed also in femur and humerus. In the description of the limb bones of *Sinanthropus* (1941a) I reported on the structure of the femur as follows: "The medullary canal of the shaft is very narrow and the walls correspondingly thick, the former occupying only one third of the least shaft

diameter whereas the ratio in modern man is one half. The thickness of the wall is, furthermore, retained proximally up to the very end of the shaft, extending thus much further than in modern man" (cf. 1941a: Pl. XIX–XXII, Figs, 39–42; Pl. XXIV, Fig. 45). The same is true of the humerus (cf. 1941a: Pl. XXXII, Fig. 58). Contrary to this thickness of the compacta, femur and humerus as a whole are not heavier than those of modern man, and even plainly inferior in this regard to the corresponding bones of the Neanderthal Man. Neither does the length of the bones differ essentially from that of modern man. The structure of the limb bones of *Sinanthropus* thus shows a surprising conformity to that of the cranial bones. This is all the more striking since the same conformity between structure of skull and limb bones exists in anthropoids but only in obverse, for the compacta of the limb bones is very thin in relation to the heaviness of the entire bone and to the width of the medullary canal (cf. 1941a: Pl. XXXI, Fig. 57). A complication arises because the gorilla has relatively the widest medullary canal and the thinnest compacta despite the heaviness of its femur, being surpassed only by the siamang. On the other hand, orang-utang comes the closest to *Sinanthropus;* the compacta of its femur shaft is relatively much thicker and extends farther upward than in modern man. It is hard to reconcile these facts with the most favored idea that there is a relation between strength of femur compacta and erect posture. For the only two types (gorilla and siamang) which can practice upright stance and gait best have a thin compacta while orang-utang, the least capable of adopting such a position, has the thickest one.

In any case, the facts are as follows: *Sinanthropus* is distinguished by a very pronounced massiveness of his cranial bones as well as those of his extremities. In both instances this massiveness undergoes a gradual diminution during evolution. Therefore, the particular structure of the skeleton is the expression of a general "constitution," specific of *Sinanthropus*, of *Pithecanthropus*—as proved by conditions of the skull at least—and of early hominids as a whole. Unfortunately, almost nothing is known about structural correlations between different parts of the skeleton of modern man. The only indication I was able to find is contained in the following passage taken from Siebenmann's studies (1898) of the pneumatization of the human temporal bone. It reads as follows: "The pneumatization of the pyramid is in an inverse ratio to the compacta formation of the skeleton. Where heavy, massive and thick-walled limb bones exist there are usually also heavy, thick and little-pneumatized cranial bones. Conversely, relatively lightly built limb bones go with cranial bones poor in compacta and rich in pneumatic cells." I am not aware whether in the years following Siebenmann's statement more precise data regarding those correlations have been published. If so, they have apparently escaped general notice.

However, it seems that massiveness and pneumatization do not produce one another, massiveness being a general feature while pneumatization is restricted to certain regions. General massiveness apparently is a primitive hominid character which disappears in the course of human evolution. There is nothing like it in living anthropoids; yet the abundant pneumatization of their skulls indicates that similar conditions may have prevailed among their ancestry. While general massiveness has been lost in their case as in man the pneumatization remained in its preferred areas. Such change also took place within the group of the early hominids themselves. While the general massiveness still prevailed in *Sinanthropus*, an extensive pneumatization set in *Pithecanthropus*.

There are still other evidences that the massiveness may be a heritage from an early hominid ancestor. New finds made by Dr. R. von Koenigswald in recent years and first recorded in a

recent paper of mine (Weidenreich, 1942) prove that contemporary with *Pithecanthropus* there lived in Java a hominid type whose mandible greatly surpassed in massiveness, and partially surpassed in size, all known lower jaws of fossil hominids and anthropoids. There are further indications that a still more enormous hominid lived in South China. The discovery of the mandible of *Paranthropus robustus* by Broom points in the same direction.

In discussing the significance of the mandibular torus I have risked the opinion (Weidenreich, 1936b): "that the protuberances are pillars left during the reduction which the formerly much bulkier alveolar process has undergone in the course of human evolution." It may be, the maxillar and ear-exostoses found in *Sinanthropus* and modern man are to be interpreted in the same way.

E. Variability, Sex, and Individual Age

The *Sinanthropus* skull material seems, at first glance, surprisingly homogeneous. This impression is true not only of the calvaria, but also of the smaller fragments of the cranial and facial elements. Skull XI, for example, looks like a replica of Skull III, and the fragment of the parietal bone representing Skull IV (Figs. 17–19) could be a portion of the parietal bone of any one of the *Sinanthropus* skulls. The features which must be considered specifically characteristic of *Sinanthropus* repeat themselves in all the specimens. All the calvariae are low in proportion to their length; all are much broader at the base than in the upper regions; all have a sagittal crest, heavy frontal and occipital tori; all have an angular torus; all have a parasagittal depression and a bumpy frontal tuberosity, despite the receding frontal scale; all show the manifold peculiarities which characterize the temporal bone and its constituents.

Nevertheless, there are certain differences. The most important is the difference in size. The maximum length of the best-preserved skulls, which guarantee reliable measurements, varies from 188 to 199 mm., and their auricular height from 94 to 106 mm. The cranial capacity ranges from 915 cc. to 1225 cc. However, it is evident from the facts cited in the preceding paragraphs that the variability was in reality much greater. Skull III, which has a capacity of 915 cc., was certainly not the smallest of the *Sinanthropus* skulls. It does not matter, in this case, that this skull cannot be counted as a fully adult specimen for Skull VI which, from the condition of its parietosquamous suture, must surely have belonged to an adult individual of advanced age probably possessed a capacity not larger than 850 cc. Whether the 1225 cc. mark as a maximum was not also surpassed is difficult to determine. Skull V was probably longer than any of the other skulls, but whether it was correspondingly higher and more capacious cannot be ascertained on the basis of external measurement of the fragment. It may be that its capacity was 1300 cc. The extent to which the anterior areas of the temporal squamae, preserved in both the large Skull V and the small Skull VI, differ from each other in size can be seen in Fig. 246 (cf. also Figs. 21, 33, and 105). Both fragments are drawn in the same natural position. The temporal squama is preserved, in both cases, as far as the sphenosquamous and the parietosquamous sutures. The latter are entirely fused in both fragments, only the edge of the squamous margin remaining free.

There is, therefore, every indication that the capacity of the *Sinanthropus* skull may have ranged from 850 to 1300 cc. The minimum capacity is thus 34 per cent less than the maximum capacity. In modern man, if we keep within the limits of normal variation taking the micro- and macro-crania described by Hrdlička (1939) as lower and upper limits, the cranial capacity

ranges from 910 to 2100 cc. The minimum capacity in modern man is therefore 43 per cent less **than** the maximum capacity.

The differences in size, and particularly in height, have, of course, influence on the indices and angles, as can be gathered from the comparison of Tables XX and XXI, but it is not true that a mere increase in size and a corresponding enlargement of the braincase will bring the skull in question into the next evolutionary stage. A *Sinanthropus* skull with a large cranial capacity which would make it fall into the range of the Neanderthal group does not become a skull of this group by the mere fact of having a brain and braincase of the same size. In my preliminary note on the discoveries of *Sinanthropus* Skulls X, XI, and XII (1937c) I made the following statement: "Its greater capacity (meaning Skull X) approaches closely the more primitive representatives of the Neanderthal group." It seems that this remark led some authors to believe that *Sinanthropus* Skull X could be regarded as a kind of transitional form between *Sinanthropus* and Neanderthal man. But such is not the case, for the *Sinanthropus* "macro-crania" nevertheless retain their specific primitive character. On the contrary, Skull V, probably the largest of all, has very pronounced primitive features (cf. Figs. 21–30, particularly Figs. 23 and 25–27).

It must be admitted, however, that the expansion of the braincase may moderate the heaviness of certain features, particularly those of a "superstructural" character. The supraorbitals of Skull X (Figs. 49 and 50) are distinctly thinner and less prominent than those of Skull XII which is smaller (Figs. 73 and 74); also, the supratoral furrow is much less pronounced in the former than in the latter. There is also a certain amount of difference in the form of the skull. Skull X is relatively narrower and therefore seems to be more slender than the broad and stout Skull XII. Skull II, the size of which cannot be estimated because of its fragmentary condition, resembles Skull X, but in this case the narrowness may be due, at least partly, to the fact that the skull is badly damaged and its restoration not quite accurate.

The most spectacular of the features of the skulls which can easily be traced back to their immediate causes are those which concern the muscular markings. The occipital torus and the relief of the nuchal plane belong in this category. As was shown above, the torus itself is a part of the architectonic framework of the calvaria and its development, therefore, independent of the bulk of the cervical musculature, that is to say, the torus is apparently of the same form and strength in all the specimens. But the form and distinctness of the linea nuchae superior, the crista occipitalis externa, the muscular depression, etc. vary considerably. They are most pronounced in Skull XII, less pronounced in Skull X, and almost completely missing in Skulls III and XI. The mastoid process can be small, as in Skulls III and XI, or its base can be large, as in Skulls X and XII. The mastoid incisure can be wide and shallow or narrow and deep, even on either side of the same skull (cf. Fig. 72).

When first confronted with these variations one gains the impression that they are due to differences in sex and one is, therefore, inclined to consider the larger skulls males and the smaller skulls females. Such an assumption is suggested, in particular, by the character of the dentition. As I was able to show in my paper on the *Sinanthropus* dentition (1937b), there are striking differences in the size of the teeth. The crown of the unworn upper canine no. 16, for example, is 14.2 mm. high, 10.5 mm. long, and 10.4 mm. broad while the corresponding figures of the unworn upper canine no. 13 are 13.6, 9.3, and 9.9 mm. The first upper premolar no. 19 is 9.2 mm. long and 12.8 broad while premolar no. 78 measures only 7.8 mm. in length and 10.5 mm. in breadth. The crown of the first lower molar no. 98 (unworn) is 8.4 mm. high, 13.6 mm. long, and 12.6 mm. broad; and the figures for the same molar no. 97 are 7.2, 11.9, and 11 mm. These examples

could easily be multiplied. Since the teeth imbedded in Maxilla III are small (Figs. 148–152) and undoubtedly belong to Skull XI, with which the maxilla was found, it is apparent that small teeth are characteristic of small skulls. And the same correlation exists in the case of the large Skull X, with which isolated large teeth were found (cf. Catalogue nos. 68, 76, 77, 86, 103; in "*Sinanthropus* Dentition," 1937b).

If we try to classify the most complete skulls of the *Sinanthropus* series according to sex on the basis of the criterion of size of calvaria and size of teeth we arrive at the conclusion that Skull X is a male skull and Skull XI a female. But such a classification encounters difficulties when the differences in size are not as pronounced as in these instances, or in cases where one must base one's classification on the calvaria alone, or on pieces of it, or even on fragments of individual bones. Since the superstructures and muscular markings are generally more distinct and heavier in males one is usually not wrong in attributing bones with pronounced markings of this kind to males. But one must always remember that, even in modern man, muscular markings can be well-developed in females, as is the case in Australian aborigines, and can be poorly developed in males, as is often the case in Malayan skulls. The problem becomes even more complicated when the question of age enters into the picture. I am not thinking of really infantile bones but of those of juvenile or adolescent individuals.

Even when all the facts of the case have been considered it is sometimes difficult to hazard a guess. A typical example of the uncertainty to which a decision can be exposed is the case of Skulls II (Black's Skull of Locus D) and Skull III (Black's Skull of Locus E). Black believed that the differences in size and form between these two skulls were not specific ones but probably due only to difference in sex and age; he, therefore, concluded that the Locus E skull was that of a male and the Locus D skull that of a female. From Elliot Smith's wording of Black's conclusion it can be deduced that he was of the opposite opinion. I am in complete agreement with Davidson Black on the point that Skull III should be regarded as that of a male. Despite its juvenile character (see later), the superstructures are heavier than in the indubitably female Skull XI; other indications are also present, particularly the pronounced thickness of the cranial wall which, in places, considerably exceeds that of the male Skull X (cf. Table XXXV). Whether or not Skull II should be attributed to a female is quite another question. In the thickness of its bones it greatly resembles the female Skull XI but it was apparently larger. It was certainly larger than Skull VI, although both were of a rather advanced age. Hence, differences in sex alone cannot explain the differences in size. There must have been, within the *Sinanthropus* population, a smaller type independent of sex. On the basis of existing materials I am unable to produce further evidence of this supposition, except for the fact that in the two groups of teeth— large and small—of which the large have been attributed to males and the small to females differences in size still remain which cannot be satisfactorily explained (cf. *Sinanthropus* Dentition; 1937b). It would not be surprising if, some day, we should discover dwarfs or at least a population distinctly smaller than those which we now consider the *Sinanthropus* type.

However, in making such a statement I want to point out the fact that, despite the possible existence of a small and a large-sized type among the *Sinanthropus* population, there is no indication of any difference in morphological character in these two forms. Some time ago, Boule presented the idea that the cave of Choukoutien must have housed two human types: one represented by what we call *Sinanthropus*, and another one, so far not verified by skeletal elements, but considered by Boule as a much more advanced human form and the true bearer of the *Sinanthropus* culture,—of which the first must have been a much more primitive creature suppressed

and hunted by the second. Boule arrived at this very far-fetched conclusion only because he considered *Sinanthropus* too primitive to be credited with the high type of cultural achievement as indicated by the implements found in Choukoutien. The case against Boule's argument has been brought out in another paper (Weidenreich, 1939a). In any event, should the *Sinanthropus* population have consisted, actually, of a dwarf type and a normal-sized one neither type had the characters suggested by Boule, for they were morphologically uniform.

In the catalogue of all the cranial and facial bones recovered in Locality 1 (Table I), the sex has been indicated. In cases in which the specimen is represented only by minor fragments the diagnosis is based on size or thickness, operating on the supposition that largeness and robustness of the bones is characteristic of males, and smallness and fragility of females. That this is not true in all cases has been shown above; but with this reservation in mind the diagnosis is fairly correct.

The determination of age involves no great difficulties, if restricted to the gross alternative: juvenile or adult. But if a more precise answer is required, the problem becomes complicated. If teeth are preserved and the individual belongs in the category of the juveniles a fairly accurate estimate of age is possible (cf. the papers on the *Sinanthropus* mandible, 1936b; and the *Sinanthropus* dentition, 1937b). If the teeth are missing, however, other signs must be sought. But whether we are dealing with juveniles or with adults one important fact must be kept in mind: —that every estimate is only a relative one since it is based on the supposition that the conditions and the changes we are using as earmarks correspond in *Sinanthropus* to exactly the same conditions as in modern man. In my paper on the rôle of the brain (1941b) I have shown that this was very likely not the case. Of modern man we have a fairly good knowledge of the age at which the various cranial sutures begin to fuse and the age at which they may be entirely obliterated. But the conditions of the *Sinanthropus* skulls, and still more so those of *Pithecanthropus*, prove that in the early hominids these processes set in much earlier and the sutures obliterate to a much more complete extent than is the rule in modern man. In this respect, the conditions of early man are more like those of the anthropoids. If this is true it may be supposed that all the stages of life cover a shorter period in *Sinanthropus* than in modern man; in other words, that a *Sinanthropus* individual whose age is judged to be fifteen years by the standards of modern man may in reality have been only ten years old or even younger.

Another point that must be taken into consideration is the fact that the cranial bones of primitive hominids are not only much thicker than those of modern man but are much thicker than those of anthropoids (cf. the preceding chapter). Whether this thickness accelerates or retards the fusion of the sutures or is without any significance we do not know. Nevertheless, it is surprising to observe that a skull like the *Sinanthropus* Skull XII which appears to belong to a completely grown-up individual still exhibits all the cranial sutures with such sharp carving of the most complicated processes and denticulations accommodating them, that it is difficult to believe that growth already had stopped. This is true not only of Skull XII but also of fragments (Skulls IV and VII) which seem to belong to adult individuals, yet have all their sutural patterns cut with extraordinary sharpness (cf. Figs. 17–19 and 37–40).

There are, on the other hand, cases in which the sutural pattern shows the same character but the bone as a whole looks like that of a very juvenile individual. In this category belongs Skull IX which is represented only by the fragment of a frontal bone (Figs. 46–48). Despite some doubt, I attributed this bone to a juvenile individual of about six years of age. The piece is remarkable for still another reason. As the figures, particularly Fig. 47, show, the temporal

line is very pronounced. General opinion tends to the belief that this line is more marked in individuals of advanced age than in younger ones. The condition of the line, or its equivalent in anthropoids, the sagittal crest, lends unmistakable support to such a suggestion. Nevertheless, the conditions seem to be different in primitive hominids. In the *Sinanthropus* specimens the temporal line seems to become less distinct as age advances. In *Pithecanthropus* Skull III (Fig. 247) the parietal section of the temporal line (lt) is well developed, and in any case clearer than in *Pithecanthropus* Skulls I and II (Fig. 259 A, B) although Skull III undoubtedly belongs to a juvenile individual in which the occipital torus (t) is only faintly indicated while Skull II is that of an adult of advanced age with obliterated coronal and sagittal sutures.

I have dwelt on these details because they illustrate the difficulties encountered when age or sex is debated. When the individual *Sinanthropus* specimens dealt with in this study are scrutinized for this purpose the youngest of them is found to be the fragment of the occipital bone (Figs. 41–45) that represents Skull VIII. This fragment shows all the characteristics of a juvenile individual: it is small, the bone is relatively thin, and the torus and the muscular markings are scarcely indicated. I have set its age at not younger than two or three years because the bone looks more robust than that of a baby. But I admit that there is no substantial basis on which the upper limit of age can be estimated. The sex may have been female, but I am somewhat in doubt as to this. The fragment of the frontal bone that represents Skull IX (Figs. 46–48) belonged to a somewhat older but still juvenile individual. This bone is thicker than the occipital bone just discussed, but it is less robust than the specimens which must still be regarded as juvenile but which are nearer to the adolescent or mature stage. Because of the pronounced temporal line it probably belonged to a male individual.

Next in age is Skull III. Davidson Black judged it to be the skull of "an early adolescent, probably at a stage of development between pubescence and adolescence." Black's chief reason for this estimate was the condition of the sutures which he described as not only patent but with spaces between the processes and denticulations so wide that they must have been filled with a thick layer of connective tissue. I agree with Black that the skull is that of a young individual, but I have gone further (1935) in claiming that it belonged to a child of 8 or 9 years of age, despite the robustness and relative largeness of the calvaria. I have four reasons for this claim: (1) the cleft in the tympanic bone is not a peculiarity of the adult *Sinanthropus* type, for it does not persist in truly adult skulls. It must, therefore, be regarded as an indication of an infantile status, even with due allowance for the fact that the opening probably took a longer time to close than it does, as a rule, in modern man. (2) The mandibular fossa of the skull is so small that only the condyle of the jaw of the *Sinanthropus* child Locus F fits in—and not that of an adult *Sinanthropus* mandible (cf. my paper on the mandible; 1936b, Pl. III, Figs. 5–8). In this lower jaw the first permanent molar is erupted and partly worn while the second one can be seen still completely embedded in the bone. This state of dentition corresponds to our age of 8 to 9 years. Moreover, mandible Locus F was found close to the site from which Skull III was taken, so that it is even possible that mandible and skull belonged to the same individual. (3) The frontal torus is weaker than that of any other *Sinanthropus* skull, and the same is true of the occipital torus; furthermore, the nuchal plane shows very little relief. This is in striking contrast to the appearance of the adult Skulls X and XII. (4) An additional feature which indicates the infantile character of Skull III is the presence of a lacrimal groove, which is absent in all the adult skulls; as I have shown above, this groove is much more developed in juvenile and fetal skulls than in adult ones, in man and anthropoids alike. This is true even in the case of the

anthropoids, in which the groove is completely absent in adults. Perhaps the development of a relatively large frontal sinus in Skull III, in marked contrast to the conditions of adult skulls, can likewise be interpreted as an infantile character.

I frankly admit that, judged on the basis of the appearance of the skull of a child of modern man of this age, Skull III does not look like the skull of a child of eight or nine. But as I have shown, there are weighty facts indicating that *Sinanthropus* and modern man cannot be judged on an equal basis in this respect. My impression is that the general process of growing up took a much more accelerated course in *Sinanthropus* than in modern man—more like that of the anthropoids.

But I have no doubt that Skull III belonged to a male. Despite its juvenile character, it is much more robust than the certainly adult female Skull XI. It resembles, in this respect, the undoubtedly male Skulls X and XII, particularly Skull XII. However, it differs from Skull XII in one interesting point. The muscular marking of the nuchal plane, which are very pronounced in Skull XII, are only faintly indicated in Skull III. This fact together with the light character of the frontal torus is another indication of its juvenile character.

Skull XII has much in common with Skull III in so far as the sutures are concerned. All are widely patent and show the peculiarities described by Black which led him to the opinion that Skull III was that of an adolescent with sutures still in the stage of growth. Certainly, if the skull is that of an adult it is that of a very young individual. My reasons for classing it as male have been discussed above.

The sutures of the two parietal fragments representing Skull IV and Skull VII, to which I have referred above, have much in common with those of Skull III and Skull XII. The skulls must, therefore, be of the same age. As the bone in each case is very thick, I have registered the skulls as males.

I have already admitted that I find it impossible to reach a definite conclusion as to the sex of Skull II. I am also doubtful of the age. Black (1931) believed that the skull belongs to a young adult in the first stage of early maturity since the sutures are still patent, except for a partial obliteration of the left coronal suture. It is true that in sharp contrast to the widely open sagittal and lambdoidal sutures the frontal and left parietal bones are very tightly engaged along the pars complicata but I could not make sure that there is a real synostosis. In any case the pars bregmatica of the coronal suture and the sagittal and lambdoidal sutures—so far as the occipital bone is present—are so wide that, in spite of its size, the skull must have belonged to a rather grown-up individual. I therefore listed it as an adolescent one.

Undoubtedly adult skulls with the sutures more or less fused are the Skulls X, XI, V and VI, the sequence in which they are arranged indicating the degree and extent of the fusion and, hence, the age attained. The male Skull X is remarkable on account of the condition of the sutures. All are widely open as in the skulls mentioned earlier except for the bregmatic section of the sagittal suture and the adjoining sections of the coronal suture (pars bregmatica and complicata). The state of the pars temporalis cannot be ascertained since the entire region on either side is broken off but the line of breakage runs partly along the sutures (cf. Figs. 52, 53, 55, 58, 59). Therefore, the fusion appears restricted to those sutures which adjoin the bregma. These conditions differ from those usual in modern man, all the more that the closing of the sagittal suture involves only the bregmatic part, the suture continuing very abruptly in a wide patent one. The injuries the skull sustained in this area will be discussed later, as will the question whether or not there is a connection between the injuries and the fusion. If the approximate age of the

skull is estimated on the basis of the sutural closure in modern man the individual may have been thirty years old, but considering the widely patent remaining suture it may possibly have been younger.

In the adult Skull XI the entire sagittal suture (Fig. 65 and 71) is closed. The coronal suture is fused too, so far as the bregmatic sections are concerned. The remaining sections are completely broken off on the left side but preserved on the right one; the suture shows here a distinct linear character but seems not to be fused. There also exists a metopic suture, already described. This is certainly closed as far as the bregmatic section extends (Fig. 71): Whether the remaining parts were also fused I am unable to tell because a fissure runs along the course of the whole suture (Figs. 63 and 70). There are two possibilities: either the suture was open and the skull was broken along the suture, or it was closed and the breakage re-opened it. The conditions of the lambdoid suture are very complicated by the occurrence of an Inca bone (see above): This Inca bone is completely fused with the parietal bones but separated from the rest of the occipital squama by a suture widely open at the left but very narrow and possibly fused at the right side (Figs. 64 and 70). All the other sutures of Skull XI are patent except for the sphenoparietal and the sphenotemporal sutures (Fig. 67). These are fused but still recognizable. As to the approximate age of this skull, the only certain thing which can be said is that it must be older than all the others described before. We have a very clear idea (for literature cf. Weidenreich, 1941b) at what age the fusion of each individual cranial suture begins but since there is great variability as to the time when the entire suture closes we are lost when we attempt to be more precise in the determination of the age. It does not help us much to know that Skull XI was certainly more than thirty years of age.

Skulls V and VI to which I have repeatedly referred are, undoubtedly, the oldest individuals of the *Sinanthropus* series. In both cases the squamous suture is fused along its total length (Figs. 21, 22, 33 and 34). In Skull V the lambdoid suture is also closed and, except for a few places, completely obliterated (Fig. 21, 23). The occipitomastoid suture, however, is open at the right side (Fragment III, Fig. 30); on the left side the conditions are obscure because of a break running along the whole suture (Fig. 22). The fragment of the frontal bone of Skull VI (Figs. 31 and 34) also exhibits the temporal section of the coronal suture with an adjoining piece of the parietal bone. The suture is visible but completely fused. Bones other than those referred to are not preserved in either Skull V or Skull VI. That, and my reasons for considering Skull V as male and Skull VI as female have already been mentioned earlier.

As to the sutures of the facial skeleton, the zygomaticofrontal suture was apparently open in all the specimens even in Skull XI, the oldest of the series in which this cranial region is preserved. The nasofrontal and the internasal sutures were patent in Skull XII but already seemingly fused, in part at least, in Skull II. In Skull XI the frontomaxillar suture is closed. In the only case in which the zygomaticomaxillar is preserved—Fac. Bone II, belonging to Skull X (Fig. 160–163)—the suture is closed and almost completely obliterated. The intermaxillar suture was open in Maxilla V (Fig. 145) and the same was seemingly true of the median palatal suture in this case and in Fac. Bone IV (Figs. 157, 158). The latter fragment probably belongs to Skull XI.

The four *Pithecanthropus* skulls and skull-fragments display a great variability if their general appearance only is considered. But if age and sex differences are taken into account the type appears much more homogeneous. This is particularly true of Skulls I and II. Skull II is, on the whole, slightly smaller than Skull I but each resembles the other so closely in minor

details that they can almost pass as twin skulls (cf. Figs. 259 and 260). The more fragmentary Skull III (Fig. 247) was of about the same size as Skull I but belonged to a juvenile individual as is revealed by the conditions of the sagittal and lambdoid sutures which are preserved, and particularly by the poor development of the occipital torus. Skull IV (Figs. 229, 230, 244) is the largest and heaviest of the series. It far exceeds Skulls I and II in thickness of the bones and in robustness of all special features both outside and inside the cranium. Particularly is this true so far as muscular markings or superstructures are concerned. Therefore, there can be no doubt that Skull IV represents a male individual while Skulls I and II, in spite of their divergence in size, represent females. The juvenile Skull III may be a male.

As to the age the conditions of the cranial sutures give some indications. In Skull I the coronal suture is fused but partly recognizable. The same is true of the sagittal suture. The lambdoid suture is evidently also closed. Only the squamous suture seems to be partly open. At any rate, the main sutures of the calvaria are ossified but not completely obliterated. In Skull II the coronal, sagittal and lambdoid sutures are completely obliterated but their course can still be determined with the aid of X-ray photographs (Figs. 257 and 258). The squamous suture is fused but partly visible and the same is true of the occipitomastoid and sphenotemporal sutures. The sphenoparietal suture is obliterated. In the juvenile Skull III (Fig. 247) the sagittal and lambdoid sutures are widely open and so, apparently, was the coronal suture along which the skull was broken off with the loss of the entire frontal bone (Fig. 261). In Skull IV (Figs. 229 and 230) the sagital suture—the frontal region including the coronal suture is missing— is fused and obliterated except for the bregmatic section where it is still recognizable. The lambdoid suture is also fused and obliterated and the same is true of the squamous, the spheno-squamous and the occipitomastoid sutures. The parietomastoid suture is likewise closed but some slight vestiges are visible.

From the conditions of the sutures, therefore, it can be conjectured that the individuals represented by Skulls II and IV may have been of about the same age, undoubtedly rather an advanced one, while the owner of Skull I was younger. If the juvenile Skull III, the age of which may have been between five and eight years, is disregarded we are at a loss in any attempt to make a guess as to their precise ages. None of the *Sinanthropus* skulls have their sutures completely closed and obliterated as have the *Pithecanthropus* skulls. Comparison with modern man also ends in failure since skulls with those sutures are very rare and, if such conditions occur, they are not necessarily signs of advanced age. As I have already said (1941b), these facts lend strong support to the assumption that *Pithecanthropus* is more like an anthropoid in having his cranial sutures fused at a much earlier age than is the rule in modern man. Such a view is sustained by the fact that the teeth which are preserved in the maxilla of *Pithecanthropus* Skull IV are only slightly worn and in any case out of proportion to what one may expect in the skull of a primitive hominid of a very advanced age, the age gauged only on the conditions of the sutures (Fig. 248).

The picture which the sutures of the *Pithecanthropus* calvaria disclose is completed by the facial sutures although it is true that these can only be tested by those of the palate (Fig. 248), owing to lack of material. The median suture is fused but, in its posterior section, still recognizable. Of the transverse suture, however, no vestige can be found although it is supposed to run across the posterior area of the fragment.

The order in which the cranial sutures of *Sinanthropus* fuse differs only in one instance from that of modern man. In *Sinanthropus* the coronal suture closes first, followed by the sagittal

suture, whereas in modern man the conditions are reversed. This fact is of some interest, for, according to Bolk (1913), in none of the primates that anthropologist examined did the coronal suture fuse first, except in *Chrysothrix*. As to *Pithecanthropus*, the material thus far available does not allow a definite statement concerning the sequence of the suture closure. But as Skull I shows the lambdoid suture is closed before the coronal and sagittal sutures are. There seems to be not an essential difference between *Pithecanthropus* and *Sinanthropus* except that the closing of the sutures begins earlier in the former than in the latter. According to Krogman (1930/31), the velocity of closure in the anthropoids is relatively great and "the vault is soon coalesced so that in early adult life we may expect complete closure." As vault closure always starts in either the lambdoidal suture or in the obelion region of the sagittal suture, *Pithecanthropus*, and to some extent *Sinanthropus*, came close to anthropoid conditions with regard to the time and sequence of the fusing of the calvarian sutures.

As to the facial sutures Frédéric (1910) has shown that, only regarding those sutures which are preserved in *Sinanthropus* and *Pithecanthropus*, the median-palatal, internasal, nasomaxillar and transverse-palatal close first, irrespective of race. The zygomaticomaxillar suture which is almost completely closed in *Sinanthropus* is among those closing later in modern man. Generally, the suture closing in man starts at the age between 31 and 40 years beginning in the posterior section of the median palatal suture. In any event the facial sutures fuse considerably later than the sutures of the calvaria. Unfortunately, there is nothing on record about the closing of the facial sutures of the anthropoids. So far as I was able to find out the palatal sutures vanish at about the same time as the main sutures of the calvaria. The complete obliteration of the transverse palatal suture in *Pithecanthropus* would, therefore, conform to the conditions of the vault sutures indicating an earlier closure than in man.

In my paper on the rôle of the brain (1914b) I have shown that there is a correlation between the relative size of the braincase and the time of the fusing of the sutures. The smaller the relative size of the braincase the earlier the sutures close, and the greater the size of the braincase the later. This agrees perfectly with the conditions shown from *Pithecanthropus* up to modern man. In the case of *Sinanthropus* the closing of the sutures occurs apparently earlier than in modern man although not in such a striking manner as in *Pithecanthropus*.

F. Reasons for Fragmentary Conditions of the Sinanthropus Skulls

In some of my previous papers on the *Sinanthropus* material (1935; 1939a; 1939c; 1941a), two questions have been discussed: (1) Why, so far, have only broken crania or fragments of other bones come to light in the Choukoutien deposit? (2) Why has the material found been restricted mainly to cranial bones? In this paper I wish to discuss particularly those occurrences of the cranial bones which have the appearance of being of pathological character or make the impression of being caused by acts of violence either during life or soon after death.

There can be no doubt that the fragmentary condition most of the cranial bones present is due to their crushing when they were embedded in the matrix from which they were recovered. A good example of such an event is the parietal bone representing Skull I (Fig. 1). If the crushing took place relatively soon after the embedding the fissures may have been more or less reconsolidated by mineralization, as in Skull I, or the pieces may have remained more or less separated from each other but in their original position. This was, for example, the case in the fragment of the parietal bone representing Skull IV (Figs. 17 and 18) which, when found, consisted of three smaller pieces that could be so completely reunited after discovery that only the

fissures which cross the fragments indicate that it was crushed. In the case of the three Skulls X, XI, and XII all were crushed apparently on the spot where they were discovered, and the subsequent dislocation of the pieces was relatively small. The crushing involved not only vaults but also individual bones; the parietal bone of Skull XII, for instance, was broken into more than fifty pieces (cf. Figs. 93, and particularly 94). But its restoration was relatively easy because the great majority of the pieces have been left in their natural position so that they could be cemented together *in situ.* On the other hand, the nasal bones of this skull lay behind and beneath the occipital bone. In the case of Skull XI, the right supraorbital was missing when the skull was found but discovered many months later in a deeper horizon. That it was broken off when the whole skull was crushed, but that greater dislocations did not take place in the fragments follows from the fact that the broken-off supraorbital fits completely with the rest of the frontal bone showing only a difference in color (Figs. 65, 66, 71, 72). As repeatedly mentioned above, at the same site where Skulls X and XI were found some larger fragments of facial bones as well as a great many small pieces were recovered. It was apparent that, originally, the face, or at least parts of it, were connected with the calvaria and have been crushed by the same force which smashed the skull.

The crushing of the *Sinanthropus* bones is not an exceptional event. The same thing happened to the animal bones which have been recovered throughout the Choukoutien deposit. The crushing apparently was the effect of a great mass of earth and stones dropping into the cave and subsequently subsiding under the pressure of their own weight. Surprising, and calling for special explanation, is the incontestable fact that the *Sinanthropus* skulls were already defective and the isolated bones partly broken into small pieces before the earth came in and covered them. First of all, entire skeletons are absent in the deposit so far as it has been explored up to date. It seems to me unnecessary to state again that the missing skeletal bones could not have been overlooked by the technicians who executed and controlled the excavation.

In order to illustrate the stratigraphic conditions of the sites where Skulls X, XI and XII were discovered, I have depicted in Figures 249–251 three sections through the Locality 1 of Choukoutien with the exact location of the three skulls and the isolated *Sinanthropus* Mandible K I (cf. *Sinanthropus* dentition; 1937b; Pl. XXX, Figs, 287 and 288). Concerning the technique used in marking the position of the finds as applied in the excavations of the main deposit and indicated in the figures, the reader is referred to my paper on this subject (1941c). Figures 249 and 251 show that Skulls X, XI and XII were recovered on the same level (Level 25). Skulls X and XI lay very close together in square J − 3. Skull XII, in square I + 2, was at a distance of about ten meters from the others. Figure 251 illustrates the same location by a vertical section. As all the indicated squares were thoroughly searched and as even the loose earth was sieved, it may be taken for granted that no other human skeletal elements but those recovered were embedded in these places. Figure 250 illustrates the conditions under which Mandible K I was found. This mandible, also, is merely a fragment. It was recovered in square I − 0 of Level 24 the exact place in the square being designated by the number 27. In this case, too, the fragment was broken into several pieces which could be united while still *in situ.* There was, however, no additional human bone discovered in this square or in any other. In Figure 250 all human and animal bones and implements recovered from this level are indicated in their exact location in the squares from which they have been excavated. The diagram shows that they were spread irregularly over nearly the entire area and that the mandible fragment was the only human bone found in Level 24.

The conditions demonstrated by these examples are typical of the entire Choukoutien deposit. They show that: (1) the distribution of the *Sinanthropus* bones both horizontally and vertically throughout the deposit is an accidental one as is that of the animal bones; (2) the bones were already isolated and defective when they came to rest in the place from which they have been recovered. It is obvious that any intentional burial of bodies is out of the question; neither could there have been an intentional interment of isolated and specially prepared heads or skulls as suggested by Professor H. Breuil (1931, 1932). At the time when Breuil advanced this opinion only skulls and skull fragments but no limb bones had been found so that there was at least a possibility of ceremonial burial of skulls. Later, however, when limb bones also were recovered showing incontestable traces of having been the objects of similar treatment (cf. Weidenreich, 1941a) it became evident that Breuil's explanation was in no wise applicable to the *Sinanthropus* material.

That the skulls have really been the objects of particular manipulations can easily be deduced from certain features which all skulls exhibit. The most striking is the lack of the central part of the base anterior to the occipital foramen. In Skull III (Fig. 234, A; cf. also Black, 1931; Pl. XII), Skull XI (Fig. 66) and Skull XII (Figs. 78 and 234, B) a part of the posterior margin of the foramen is preserved whereas in Skull X (Fig. 54) the greater part of the base is missing and in Skull II (Fig. 10) the entire base. Still more important as a correct interpretation of this occurrence is the fact that no missing pieces of the base were discovered in spite of all the searching for them. This holds particularly true for Skulls X, XI and XII where, as already mentioned above, such small facial bones as the nasal bones were, eventually, found beneath the occiput while no vestige of the missing temporal bone or the body of the occipital bone was discovered. This suggests that the bones of the base or other missing parts of the skull were already removed when the skull was embedded in its matrix. The particular nature of these imperfections recalls strikingly those described by Blanc (1940) in the case of the Neanderthal Skull in the cave of Monte Circeo (cf. the photograph of the skull in basal view in Blanc's paper, p. 285). The skull, found on the floor of the empty cave was apparently undisturbed in all the time past since the last Interglacial Age. All the base around the occipital foramen is missing in this case.

In previous publications I have interpreted the constant absence of the basal parts in question as an indication of their having been deliberately removed in order to get access to the contents of the braincase. This is also Blanc's interpretation of the defect in the Monte Circeo skull; he speaks of signs of mutilation after death in the form of a symmetrical opening at the base and refers to modern Melanesian skulls in which the same injuries occur as the effects of ceremonial cannibalism.

Apart from the basal defects, the *Sinanthropus* skulls and skull fragments show other peculiarities suggesting acts of violence which have affected the bones. As all the cranial bones are more or less crushed by forces acting on them from the outside before or after mineralization, it is difficult to decide at which time the event which caused the bones to be broken took place. But Skulls X and XII, to begin with, display injuries which leave no room for any other explanation but of their having been brought about by blows on the skull during life. In Skull X there is a deep and long depression on the left side of the frontal and parietal bones that runs almost parallel to the sagittal suture, as already reported above in the special description of the skull (cf. Figs. 51–53, 55, 57 da, 59 da). The depression begins near the vertex, crosses the coronal suture and ends half way down the frontal squama on a broad fissure apparently of a later accidental provenance. A depression of very similar nature is recognizable in Skull XII. This

injury which has more the appearance of a cut is found close to the sagittal margin of the right parietal bone and extends from the suture just behind the vertex forward and laterally toward the coronal suture (Figs. 77, 70, 83). Both injuries contrast very strikingly with their background when photographed with adequate cross-light as depicted in Figures 252 and 253.

Neither the depression of Skull X nor that of Skull XII can have been caused by a blow which hit them when they had already lost their organic substance. In such a case the bone splinters like glass but will not become depressed. Depressed fracturing, that is to say a compression of the bony substance itself, can only occur if the bone is still in a state of plasticity which means that it has not only preserved the organic substance in the bony tissue but also the contents of the spaces of the cancellous tissue and the bony canals, and, more than this, the skull must have been covered by the scalp. In other words, the injuries described must have been inflicted during life or soon after death. Against the latter assumption the fact can be adduced that the injury of Skull X (Fig. 252) is not fresh, the surface being completely smooth and looking like an old scar. Therefore, the skull was struck, not after death, but when the individual was alive; the individual must have survived the blow. There is indeed only a very insignificant prominence of the interior table of the skull and no sign of splitting. In the case of Skull XII (Fig. 253) the surface of the cut is slightly rough and there is a distinct knob-like prominence of the interior table but no splitting. The thickness of the bone may have proven a good protection. In Skull XII there is also a scar of smaller dimensions on the left side of the forehead (Fig. 79, sca); in this case the surface is less smooth, nevertheless the injury looks more like a scar than a wound.

Skull X exhibits a further depressed fracture of much smaller dimensions than that of the left side. This depression is circular, its diameter amounting to about 20 mm., and situated almost on the mid-line a little behind the vertex, mainly on the right side and affecting the sagittal margin of the left parietal bone. In Figures 50 and 56 the injury is recognizable. In this case the interior table is broken around an oval line and projects into the cavity. Although the surface of the fracture is smooth, I doubt that this injury can be regarded as a healed lesion.

Skull XI shows two injuries the nature of which is easier to understand. They concern the parietal bones on either side. The left bone exhibits a typically semi-circular, depressed fracture with fairly sharp borders situated just behind the vertex of the parietal tuberosity (Fig. 67 da) and at the edge of a large irregular defect which extends over the superior and posterior parts of the bone. This fracture is apparently the result of a heavy blow breaking the bone into smaller pieces along the transverse line that crosses the depressed area. The pieces are missing and could not be recognized among those found in the place where the skull was recovered. The second injury occupies an almost identical place on the right side (Fig. 68 da). The only difference is that the depressed area appears shallower, nor were the parts of the parietal bone lost. They were recovered and used for the restoration. But it is evident that the depressed area represents a center from which three fissures start: one running backwards, one medially and one laterally, the two latter following the same straight line. In the first described injury the inner side is broken away; in the second it is in place but does not show particular fracturing, except for a slight prominence of the broken pieces which border the transverse fissure.

A depressed fracture which looks strikingly like that of the left side of Skull XI is found in the fragment of Skull VI (Figs. 32 and 35, frc). Skull VI consists, as described above (cf. also Weidenreich, 1936/37), of only three isolated fragments: one of the frontal bone, one of the squama of the temporal bone, and one of the left parietal bone. The fragment of the parietal

bone itself embraces three smaller pieces; F I and F II which are separated by only a narrow fissure while piece F III was recovered at some distance from them but fits completely into the fracture of the anterior-inferior margin of the main fragment. Where the three pieces join each other there is a typical depressed fracture outlined by sharp borders in the center of which the three fissures meet. There can be no doubt that the bone was hit in this place by a blow that depressed the bone and caused the fracturing.

Apart from the described injuries each skull shows abrasions, smaller or larger, deeper or more superficial. One of the latter kind is depicted in Figure 68, ij. The abrasions are particularly abundant in Skull III (cf. Davidson Black, 1931, Pls. XI–XVI). Whether they are the result of violent acts before or immediately after death or the result of later erosions is, in many cases, difficult to decide, but whatever their interpretation may be it has no direct bearing on that of the main injuries. For them there remain three possibilities. The lesions can be caused by stones falling from the roof of the cave on the individuals living in it. They can be inflicted by weapons of a hostile tribe, or they can be caused by the bites of big carnivores having their dens near-by. The depressed fractures of Skull XI and VI could well be the result of blows by falling stones, provided they hit the individual when alive or soon after death. In Skull VI (Fig. 35) where the injured area is small but the wound is deeply penetrating the stone must have been pointed and must have dropped down from a considerable height; in Skull XI (Figs. 67 and 68) the stone must have been larger and had more rounded contours. The injuries of Skull X (Figs. 252 and 253), however, are obviously of an entirely different nature; they look like incisions made by cutting implements.

Blows inflicted on living individuals or corpses by stones falling accidentally cannot be held responsible for the destruction of the base of the skull. This fact, together with the cut-like lesions, rather points to injuries incidentally practiced by man. There are other indications pointing in the same direction. In a previous paper (1936/37) I called attention to a scratch-like shallow groove with straight rims found near the upper margins of the parietal bone fragment of Skull VI (Fig. 35 sa). The groove starts from an irregular indent at the margin and ends at the posterior margin of the fragment. Such an injury can be produced by a small scraper. It is certainly not a pure accident that Skull II displays quite a similar furrow running along the sagittal suture (Figs. 9 and 15 sa). The scratch begins in the obelion region of the posterior end of the fragmentary parietal bone and terminates, gradually narrowing, at the coronal suture. Its length amounts to over 35 mm. and its width to 3 mm. at the broader end. There is, of course, the possibility that the artificial grooves of Skull II as well as VI are due to the accidental rubbing of a sharp stone over the surface; yet there are other scratches and cuttings which cannot so easily be interpreted in this way. In the paper (1936/37) just referred to I have described several irregular scratches that cover the temporal squama of the fragment representing Skull V (cf. 1936/37, Fig. 17, p. 463). In addition the breakage of the superior margin of this fragment is composed of a number of shorter breakages with straight contours which give the impression that the missing parts were cut off piece-meal with implements. The photograph (Fig. 21) shows the scratches and cuts very clearly, in particular the one designated by "ac." That the injuries have not been made by implements used in recovering the material can be proved incontestably in this case by the fact that the fragment in question was covered all around by a thick coat of lime incrustation and that the injuries came to light when this was removed.

The peculiarities of Skulls V and VI lead us to a discussion of the third alternative concerning the sources of the injuries. In my paper on the extremity bones of *Sinanthropus* (1941a) I represented as a probability that at least some of the split bones were cracked and gnawed by big carnivores. The presence of hyaena and its use of the cave as a den is proved by the discovery of abundant skeletal bones scattered all over the cave and, in addition, by its coprolites forming thick layers in some horizons (cf. Pei, 1934): On the other hand, it seems to be certain that the lengthwise splitting involving the greater part of the shaft bones, cannot have been executed by carnivores but must have been done by man. When carnivores are considered as possibly being responsible for cracking the cranial bones there remains to be examined which of the injuries described may reasonably be attributed to bites. There can be no doubt that the conditions of the fragments of Skull VI correspond best to the premises of such an assumption. First, the three main fragments have been recovered from the same horizon (Layer 8), together with some teeth, but spread over a rather vast area. They could, therefore, have been dragged away by a carnivore. Secondly, the injuries inflicted on the fragments of the parietal bone (Figs. 32 and 35) show all the character of having been caused by bites. The depressed fracture could be caused by a carnassial and the indent of the superior margin with its irregular border and scratches at the surface starting from the indent could have been caused in the same way. The scratches and cuts at the superior margin of the temporal-parietal fragment of Skull V (Fig. 21) could also be the effect of bites. Zapfe (1939) tried to find out experimentally how living carnivores, in particular hyaena, tackle long bones. But, unfortunately, he worked only with long bones and did not extend his experiments to skulls and cranial bones. But in the latter case the skull has to be broken into pieces before the bones are accessible to the animal. In the case of Skull V which consists of the fragment of the left temporal bone with the adjacent parts of the parietal and occipital bones (Fig. 21) it is obvious that the skull before being broken into pieces had been deprived of its central basal portion as had Skulls III, X, XI and XII. For, as Figures 23 and 26 show, this part is missing in the fragment while the line of breakage exactly corresponds to that of the other skulls. It is of course possible that a hyaena or any other carnivore might have dealt with an intact skull by first cracking the face and then proceeding to the vault. But considering the size, form and thickness of the *Sinanthropus* vault it is difficult to imagine how the animal could find adequate points at which to drive its teeth and crack the vault by seizing it between its upper and lower jaws. Mollison (1938) has advanced the opinion that the two injuries on the left side of the Rhodesian Skull, one at the temporal region and the other at the mastoid process, were caused by the canines of a carnivore and the scratches on the surface likewise by teeth. The author is apparently right in tracing the two injuries back to the same agent. Yet I consider it impossible that they were caused by a bite. First, the two lesions are almost circular and only 18 mm. apart, at their closest point. Therefore, only a very small carnivore could have been the offender, for even a medium-sized dog has the canines set at a greater distance. A small carnivore, however, would not have had the force to penetrate such heavy bones. In addition, if the injuries were caused by being grasped between the canines of upper and lower jaws vestiges of the opposing tusks must be recognizable at a reasonable distance from the injuries. But there is nothing to be interpreted in this way. Therefore, we cannot refer to other cases as examples of bites of carnivores inflicted on completely intact human skulls. On the other hand, there is evidence of the skulls of early man having been subjected to the actions of cutting implements. The first related case concerns the Ehringsdorf Skull (cf. Weidenreich, 1928). Its frontal bone exhibits on either side marks of blows the character of

which does not admit of doubt that they have been caused by cutting implements (cf. Weidenreich, 1928; Figs. 9 and 10). The same bone shows furthermore a depressed fracture with typical splitting of the internal table (cf. Figs. 11 and 12; my paper). In addition the recently discovered skull of Monte Circeo exhibits an injury in the region of the right temple and eye, according to Blanc (1940: see also above), caused by a blow during life. The skulls of Ehringsdorf and Monte Circeo belong to the last Interglacial Age of Europe and are, therefore, younger than *Sinanthropus*, but they prove in any case that the practice of man to war against his own kin is a very old one.

If we recapitulate all the facts the following is evident: (1) all *Sinanthropus* skulls lack the central parts of the base; (2) some of them show lesions or scars at the top of the skull the form of which indicates that they had been inflicted by ax- or knife-like implements; (3) some skulls exhibit, on the upper part of the vault, depressed fractures with radiating fissures indicating that a blow had hit the skull while it was impressible; (4) there are cranial bones and fragments of them with irregular indents at the injuries and with scratches on the surface. My verdict is that the destruction of the base and the blows on the top of the skull are the incidental work of man, although the possibility cannot be entirely excluded that at least those lesions which indicate they were produced by pointed or blunt agents may have been caused by stones falling from the roof of the cave on a living individual. Later on the skulls were broken as carrion by carnivores, probably hyaenas, which lived in the cave and cracked the bones as long as they were fresh.

To the additional question, why were only parts of the cranial skeleton (calvaria, mandibles) and fragments of the limb bones recovered, I am unable to offer any answer but that given in my previous papers: it has to be taken as certain that only selected parts of the *Sinanthropus* bodies were present in the cave. There is, of course, the possibility that carrion-eaters have eaten the bones without leaving any except the recovered ones. Admitted even that the carnivores can dispose of entire bodies, the number of the *Sinanthropus* individuals whose presence in the cave is proven by the recovery of their teeth or skeletal parts is such a high one (over forty) that it appears utterly improbable that the hyaenas have eaten all the trunk and limb bones of these forty individuals and leave over a relatively small piece of each for our research. In the case of the Monte Circeo skull nothing was found of the skeleton although there were plenty of animal bones lying around on the cave (cf. Blanc). My early suggestion still stands, namely: that the strange selection of human bones we are facing in Choukoutien has been made by *Sinanthropus* himself. He hunted his own kin as he hunted other animals and treated all his victims in the same way. Whether he opened the human skulls for ritual or culinary reasons cannot be decided on the basis of the present evidence of his cultural life; but the breaking of the long-bones of animals and man alike, apparently for the purpose of removing the marrow, indicates that the latter alternative is the more likely. The remains of his meals became the prey of his predatory neighbors at the foothills of Choukoutien.

In *Pithecanthropus* the conditions differ principally from those of *Sinanthropus*. They agree in the fact that, up to the present, no intact skulls of *Pithecanthropus* have been recovered, and that in Skull I as well as in Skull II the base is missing. Skull IV in which the base is preserved resembles the *Sinanthropus* skulls in that the skull exhibits distinct signs of violence. The skull was crushed and telescoped (cf. Figs. 229, 230, 244) evidently when the soft parts surrounded the bones; for otherwise they could not adhere together and be mineralized in their present positions. But all the *Pithecanthropus* material recovered thus far came from volcanic

deposits and was transported by mud streams together with pebbles and boulders (cf. H. de Terra, 1943) to the site where it was recovered. The crushing may therefore be the consequence of elemental accidents rather than of the incidental actions of man.

G. An Analysis of the Structural Characters of the Sinanthropus Skull: A Summary

This chapter is chiefly a repetition of data reported in the preceeding chapters and has to be considered, therefore, as a summary of the features characterizing the *Sinanthropus* skull. In order to facilitate the better comparison of the resemblances and differences between this skull and that of other hominids and anthropoids, I am following Marcellin Boule, an example adopted by Theodore McCown and Sir Arthur Keith who listed the characters of the man of La Chapelle-aux-Saints (1911) and the Mount Carmel population (1939), respectively, side by side with the compared types. In so doing the fortuitous character of the material must be taken into account, as it consists, in nearly all cases, of very few and sometimes rather defective specimens. Therefore, each verdict is based on and refers to only those objects which are at hand and suitable for comparison.

I. GENERAL FORM

1. Calvaria

1. The maximum length varies from 165 to 205 mm. (average 194 mm.) and so falls within the variation average of Neanderthal and modern man. The *Pithecanthropus* skull is shorter than the *Sinanthropus* average while that of *Homo soloensis* shows the same length, except for Skull V which is of extraordinary length exceeding not only the longest *Sinanthropus* skull but that of modern man as well. The anthropoids are by no means uniform and, in addition, it is difficult to determine the length because of the heavy superstructures developed by male orang-utang and gorilla.

2. The opisthocranion coincides with the inion. This is the same in *Pithecanthropus, Homo soloensis* and some Neanderthalians while in other Neanderthalians and modern man the inion has shifted toward the opisthion and the opisthocranion toward the lambda. In the anthropoids the conditions are just reversed: the inion is placed nearer to the lambda and the opisthocranion nearer to the opisthion.

3. The maximum breadths of the vaults coincide with the biauricular breadth (average 145 mm.); the breadth at the level of the temporal squama or at that of the parietal bone is distinctly smaller. The same conditions are true of *Pithecanthropus* Skull IV and some of the Ngandong skulls. In other Ngandong skulls and in *Pithecanthropus* Skull II the biauricular breadth is less pronounced. In modern man the biauricular breadth is not only smaller than the breadth above, or at least equal to it, but is considerably smaller than in *Sinanthropus*, its average amounting to only 121 mm. In anthropoids the biauricular breadth far surpasses the breadth of the vault proper.

4. The total height amounts to 115 mm. This is both absolutely and relatively much less than in modern man with an average of 134 mm. In *Pithecanthropus* the height, which can only be estimated, could not have been more than 105 mm., while it rises in the Ngandong skulls to 122.5 mm. The Neanderthalians range between the Ngandong skulls and modern man with an average of about 125 mm.

5. The average length-breadth index of the *Sinanthropus* skulls amounts to 72.2 so that they must be classified as dolichocranial. Dolichocranial are also *Pithecanthropus*, the Ngandong and Neanderthal skulls and the greater part of the races of modern man. Among the anthropoids, gorilla and orang-utang show a wide range from brachycranial to dolichocranial individuals. The length-breadth index, therefore, proves useless in fixing the type character.

6. The length-height index which is of much greater significance than the length-breadth index because of its relation to the height amounts to 59.6. The index is far below that of modern man which totals 75 for the average. The *Sinanthropus* skull is hyperchamaecran, the average skull of modern man hypsicran. In *Pithecanthropus* the index can only be estimated vaguely owing to the broken condition of the skulls. In the Ngandong skulls the index, amounting to 62.5, is a little higher than that of *Sinanthropus* and it is higher still in the Neanderthalians, their average totalling about 64. In anthropoids the index is difficult to compute owing to the uncertainty in determining the maximum length.

7. The breadth-height index is 75.6 while the length index amounts to 95.0 in modern man. The *Sinanthropus* skull is hypertapeinocran that of modern man metriocran. *Pithecanthropus* Skull II has a slightly higher index than the *Sinanthropus* average (77.8) while the Ngandong skulls come closer to modern man with an index of.84.2. The Neanderthalians with an index of 87.0 easily fall into the range of modern man (lowest group 85.5). The anthropoids show a great variation in this regard apparently due to the fact that the medium breadths are small in the female orang-utang but very great in the male gorilla. The index ranges from 75 to 112, so that it comprises all the average figures of all the hominid types compared.

8. The length-height index, using the nasion-opisthion line as the base of the vault and the vertex as the apex, amounts to 69.4. The corresponding figure for modern man is 91.0; for *Pithecanthropus* Skull II it is 64.2; for the Ngandong skulls it is 69.0; for the Neanderthalians 77.7, and for the anthropoids 54.0. When this index is taken as a gauge for the classification of the hominid types *Pithecanthropus* represents the lowest stage. Very close to him are *Sinanthropus* and *Homo soloensis*. The Neanderthalians follow at a greater distance and then, at a greater distance still, comes modern man. The anthropoids, on the other hand, are about as far below the *Pithecanthropus*-group as modern man is above the Neanderthalians.

9. The average cranial capacity amounts to 1075 cc. (c. 850 to 1300 cc.). *Pithecanthropus* has an average capacity of only 860 cc. (c. 775 to 900 cc.) while that of the Ngandong skull totals 1100 cc. (c. 1035 to 1255 cc.). The skulls of the Neanderthal-group vary from about 1200 cc. to over 1600 cc. with an average for all types of about 1400 cc. In modern man, all the races and both the sexes taken together, the average can be estimated at 1350 cc. with a range from c. 900 cc. to 2100 cc. However, Mongols have an average of 1400 cc.; Europeans and Polynesians 1370 cc.; Negroes 1300 cc. and Melanesians and Australians 1270 cc. In the anthropoids the average amounts to 415 cc., and the largest capacity ever found is that of a male gorilla totalling 623 cc.

10. The *Sinanthropus* skull is chiefly characterized by lowness, (cf. nos. 6, 7, 8); by having its greatest breadth at the base, namely at the level of the angular torus and the supramastoid crest; and by steadily decreasing from that level to the top. *Pithecanthropus* is slightly lower but the breadth conditions are the same; much pronounced in the male Skull IV while they are less in the female Skull II. The Ngandong skulls agree with *Sinanthropus* as to lowness and partly as regards breadth. The skulls of the Neanderthalians are much higher and so is the level of the greatest breadth. In modern man the vault is still higher than in the Neanderthalians

and corresponding to this change the greatest breadth has shifted upward, so that the basal breadth is not only relatively but absolutely smaller. The anthropoid skull is considerably lower than the *Sinanthropus* skull and the basal breadth exceeds that of the parietal part of the vault by far.

11. The forehead, as a whole, is receding; the frontal inclination-angle, referred to the nasion-opisthion line as base, amounts only to 58° whereas it totals 72.6° in modern man. In *Pithecanthropus* the angle is a little greater (60°) while it is somewhat smaller (57.6°) in the Ngandong skull. The Neanderthalians have a much greater angle, reaching the average of 66.3°. In the anthropoids the angle is 52.5°.

12. In spite of the receding forehead there is a distinct bump on the frontal squama of most of the specimens. In *Pithecanthropus* and in the Ngandong skull alike the bump is missing and the squama is flat. The Neanderthalians vary; in the Rhodesian skull the squama is flat; the Spy and La Chapelle skulls show a slight bump while this is more pronounced in the skulls of Ehringsdorf, Galilee and Mount Carmel. As to the anthropoids, the forehead is flat in the gorilla and male orang-utang; a slight bump exists in the chimpanzee and a still more pronounced one in the female orang-utang.

13. There is a sharp bend between the upper and lower scale of the occipital bone the angle amounting to 103.2. In *Pithecanthropus* the angle is the same but it is more pronounced in the Ngandong skull (98.2°). As to the Neanderthalians, there is only an angle totalling about 110° in the Rhodesian skull while the others approach modern man where the angle is replaced by a continuous curve. In the anthropoids there is a sharp bend only when the occipital crest is very pronounced.

14. The flatness of the *Sinanthropus* vault is also manifest in the sagittal cranial curvature. Its index amounts to 44.0. *Pithecanthropus* shows the same index while the Ngandong is a little more curved (42.3). The average index of the Neanderthalians totals 40.9 and that of modern man 36.6. In anthropoids the index is much higher than in hominids, the average amounting to 54.7.

15. The length of the base as represented by the nasion-basion line amounts to about only three-quarters of the nasion-opisthion line. This ratio holds good not only for *Sinanthropus* but for all hominid types including *Pithecanthropus*. It is much higher in the anthropoids where the nasion-basion line totals 85 and more per cent of the nasion-opisthion line. The difference is due to a difference in the position of the occipital foramen which holds a rather central position in all the hominids whereas it is much more to the rear in the anthropoids. As there is no indication of a substantial change in this condition during human evolution, we must regard the central position as a primitive feature characteristic of hominids.

16. The base of the hominid skull shortens increasingly as is indicated by the increase of its deflection and the change in the position of the klition, porion and internal auditory porus in relation to the nasion-opisthion line. In *Sinanthropus* and the other hominids the porion is situated on or above a horizontal plane drawn through this line while it remains below that line in the anthropoids. In *Pithecanthropus* the porion lies at the exact level of the plane but high above it in modern man. *Homo soloensis* is next to *Pithecanthropus*, then follows the Neanderthalians. The klition occupies a position similar to that of the porion. It is not preserved in *Sinanthropus* but it can be deduced from the location of certain landmarks which are preserved, noteably those of the pyramid, as, for instance, the internal auditory meatus, that the klition

lay above the nasion-opisthion plane. In modern man it is high above this plane while in anthropoids considerably below.

17. The two supraorbital ridges are very heavy and project far. They are continuously connected by a glabellar torus which is equally robust in structure. There is, therefore, a uniform frontal torus which is separated from the rising frontal squama by a well-defined furrow— the supratoral sulcus. The supraorbitals exhibit no tendency to be separated into medial and lateral portions. In *Pithecanthropus* the supraorbitals have the same general character as in *Sinanthropus* and the existence of a glabellar torus may be supposed. But the supratoral sulcus is missing. The conditions in the Ngandong skull are the same as in *Pithecanthropus:* there is no sulcus, the supraorbital structures continuing immediately into the squama. As to the Neanderthalians, there is a great variation. The Rhodesian skull closely resembles *Pithecanthropus* and the Ngandong skulls. It even exceeds them in the matter of heaviness. The frontal tori of the Galilee and Mount Carmel skulls exhibit the same general characters as the *Sinanthropus* skull, there even being a distinct supratoral sulcus. In the Neanderthal skull of La Chapelle-aux-Saints the glabellar torus is less developed and there is an indication that the supraorbitals are separating into a smaller lateral and still heavy medial portion; they are also separated from the squama. In modern man the glabellar torus is indicated in many Australian and Melanesian skulls while the supraorbitals have undergone an almost complete reduction so far as the lateral portion is concerned; the medial portion is still represented by the more or less well developed superciliary ridge. The sulcus however has disappeared, the entire structure having merged into the squama.

18. *Sinanthropus* has a distinct sagittal crest. It begins above the frontal tuberosity and fades out in the obelion region. A flattening of the vault on either side—parasagittal depression —stresses this structure. At the bregma the crest broadens into a cross-like eminence which extends along the bregmatic section of the coronal suture on either side. In the *Pithecanthropus* Skulls I, II and III the crest, especially the bregmatic eminence, is indicated. In Skull IV where the bregma region is missing the parietal section of the crest is very pronounced. The Ngandong skulls closely resemble the *Pithecanthropus* skull. In some of the specimens the crest, especially the bregmatic eminence, is well developed; in others it is only faintly indicated. Among the Neanderthalians the frontal and bregmatic portion is very distinct in the Rhodesian Skull. There the parietal portion consists rather of a parasagittal depression of the vault than of an elevation of the bone in the mid-line. Neanderthalians also closely resemble Rhodesian man in the development of the frontal and bregmatic portions and the loss of the parietal part of the crest. As to other Neanderthalians, Spy I comes close to the Rhodesian skull while the remaining show a well-rounded surface; in Skhūl V alone there is a slight parasagittal flattening. In modern man the sagittal crest is very common among Australians and Eskimo skulls. Nor is it rare in the Amerinds and Northern Chinese. In these cases however the appearance of the crest differs from that of *Sinanthropus*. The prominence is not restricted to the immediate surroundings of the sagittal suture but has broadened toward both sides, consisting largely in a flattening of the entire parietal region above the parietal tuberosity. In anthropoids there is nothing which could be compared with the sagittal crest of the hominids. For the sagittal crest of the great apes is equivalent to the temporal line which, in all the hominids, remains completely separated and runs far below the sagittal crest.

19. There is a well-developed occipital torus. This not only extends across the entire occipital bone but also laterally and then forward to the mastoid region. The mastoid angle of

the parietal bone is occupied by its very distinct continuation—"angular torus"—which continues, in its turn, into the supramastoid crest. The occipital torus itself is demarcated from the occipital planum by the supratoral sulcus. The demarcation from the nuchal plane consists, in the female individuals, only of a faintly developed line while male individuals exhibit a deep muscular depression on either side that forms an edge-like superior nuchal line. The central portion of the torus is continuous in its entire extent and thickest in the middle. In *Pithecanthropus* the same difference between female and male individuals is recognizable. With slight deviation the relief of the torus is more obscured in the female and much more accentuated in the male. In general, the Ngandong skulls resemble the male *Pithecanthropus* skull, nevertheless they exhibit a definite tendency toward disintegration of the structure. Such a tendency is especially pronounced in the Neanderthalians: The torus structure is confined to the occipital bone; the singular prominence of the parietal bone has completely disappeared and the central part of the torus shows all the signs of being gradually absorbed into the general level of the occipital plane. In modern man a torus is found only occasionally in primitive races. In many cases there is nothing left but series of lines which appear as muscular markings. The external occipital protuberance is a purely modern formation developing as an ossified attachment of the nuchal ligament. In the anthropoids there is no true equivalent of the occipital torus. Their nuchal crest corresponds as little to the occipital torus as their sagittal crest corresponds to the hominid formation of the same name. Only the faint elevation recognizable in young anthropoids as the basis from which the nuchal crest develops may be recognized as a structure of the same nature.

20. The frontal torus, the occipital torus, its lateral continuation the angular torus and the sagittal crest are parts of a general reinforcement-system which forms the architectural framework of the calvaria. The system consists of four components. (1) A basal series comprising a pre- and post-otic section which contains, from front to back, the frontal torus; the fronto-maxillar process; the zygomatic arc; the supramastoid crest; the angular torus and the occipital torus. (2) A sagittal arch extending from the foramen caecum to the occipital foramen, visible partly outside and partly inside of the vault. The former presents the sagittal crest which runs up from the upper end of the central tuberosity to the obelion region. The latter continues with the former and consists of the internal frontal crest and the vertical arm of the cruciate eminence. (3) A basic center chiefly represented by the bodies of the sphenoid and occipital bones. (4) A transverse connecting system with an anterior and posterior branch. The anterior branch is the Sylvian crest which continues into the posterior edge of the lesser wing of the sphenoid (see no. 43). The posterior branch is the pyramid. The basic center and the transverse system are parts of the inside structures of the calvaria.

The whole framework is well developed in *Sinanthropus, Pithecanthropus* and the Ngandong skull, although the latter shows signs that the basic center and the transverse system are disintegrating. In Neanderthalians the disintegration has made further progress in all its components, particularly as regards the strength and continuity of the different structures. In modern man very little is left of the original character of the framework, but the principle of its arrangement is still recognizable. Best preserved are the internal structures of the sagittal arcs, the basic center and the posterior branch of the transverse basic system which serve as attachments for the processes of the dura mater. In the anthropoids there is nothing which compares with those structures in the primitive hominids for strength, distinctness and completeness, except for the pre-otic section of the basic ring system. The sagittal and nuchal crests are not

equivalent to the sagittal crest of the hominids or to the occipital torus and the torus angularis. Even the internal structures of the sagittal arc, namely, frontal and Sylvian crest and the cruciate eminence, are either missing here or but faintly indicated. The anthropoids differ remarkably, therefore, from the hominids in these features.

21. The architectonic framework of the *Sinanthropus* calvaria appears to be only a special differentiation within the general massiveness of the cranial bones. If the thickness is expressed by an average index giving the mean of the measurements of the four chief bones of the vault— frontal, parietal, temporal and occipital—this index stands at 9.7 mm. *Pithecanthropus* has bones even thicker and its index totals 10.0. The Ngandong skull, for which no exact figures are available, is not inferior to *Pithecanthropus*. The Neanderthalians, with the Rhodesian skull excelling others, have an index of 7.2 while modern man closes the list with an index of 5.2. That is to say, about half the thickness of *Pithecanthropus*. There is therefore a gradual reduction in the index from primitive stages to modern man, a condition which conforms perfectly with the reduction of strength and extension of the architectonic framework. The anthropoids exhibit a striking contrast to the hominids in this feature. Even in the male gorilla the thickness of the cranial bones does not surpass those of modern man. There is, therefore, the same difference between anthropoids and hominids as in the architectonic framework of the calvaria.

22. In *Sinanthropus* all the cranial bones not only those of the vault but also those of the base are very massive. Their thickness depends not so much on an evenly proportional increase in the three structural layers which compose the bones as in a peculiar thickening of the outer and inner tables. In conformity with this thickening the pneumatization is restricted and in no case corresponds to the heaviness of the bones themselves. This is especially evident in the conditions of the frontal sinus. In all skulls the supraorbitals are exceedingly massive and are formed of narrow-meshed cancellous bone tissue. The frontal sinus is small and confined to the region of the glabellar torus. Only in the juvenile Skull III is the sinus larger but even then does not extend beyond the interorbital region. The cellulae ethmoideae are, however, well developed and as numerous as in modern man. There is no pneumatization in the base of the pterygoid process or in the palate but a rather expanded one in the temporal bone: the air-cells in this are larger and extend in all directions beyond the points reached by modern man. The maxillary sinus also is larger than in the latter.

Pithecanthropus and the Ngandong skull differ from *Sinanthropus* in that they possess very large frontal sinuses which extend upward, backward and markedly in a lateral direction. In *Pithecanthropus* Skull IV there is a large sinus in the base of the ptergoid process. As to the pneumatization of the other bones nothing definite is known. The Neanderthalians, so far as we have any data, agree markedly with *Pithecanthropus* and the Ngandong skulls. In modern man the pneumatization varies greatly in occurrence and extent. In primitive races, for example in the Australian aborigines, the frontal sinus is very small or completely lacking; in other races or in individual cases it reaches large proportions. Among the anthropoids, chimpanzee and gorilla, particularly the males, possess enormous sinuses which extend far into all the bones connected with the nasal cavity. Only the orang-utang is an exception; the frontal sinus is either entirely lacking or represented by a small upward extension of the ethmoid sinus. In all anthropoids, moreover, there is a pronounced tendency to dispense with all the partitions of the main sinuses, merging the whole into one large space. This is particularly true of the ethmoid and sphenoid sinuses (see also no. 33).

2. Face

23. The face is relatively small and only slightly prognathous when using the upper facial triangle as the basis of measurement. This triangle is composed of the nasion-basion, nasion-prosthion and basion-prosthion lines as sides, with the corners serving as angles. The size of the angle at the nasion indicates the degree of prognathism. The area of the triangle itself can be used in gauging the approximate size of the upper face when compared with a similarly simplified mid-sagittal section through the calvaria.

24. The ratio between the size of face and calvaria as defined in no. 23 is 28 in *Sinanthropus* (female); in male *Pithecanthropus* is 37; in male Neanderthalians (Rhodesian and La Chapelle-aux-Saints skulls) 33. In female Neanderthalians (Gibraltar Skull) the ratio amounts to 22 and in modern man (both male and female) to 22. In anthropoids the ratio is much higher, totalling 74.

25. The nasion angle of the upper facial triangle in *Sinanthropus* is 72°; thus according to the classification based on this type of measurement the face is prognathous. In *Pithecanthropus* (Skull IV) the angle amounts to 81°; in the Neanderthalians (average) to 69° and in modern man (average) 67° with a minimum value of 54°. In the anthropoids the angle ranges from 92° to 114° (average 100°).

26. The size of the basion angle of the upper facial angle gives an indication of the height of the face. More precisely, it indicates whether and to what extent the face has developed in a downward direction. This angle is 40° in *Sinanthropus;* 43° in *Pithecanthropus* Skull IV; 49.5° in the Rhodesian Skull; 42° in other Neanderthalians and 42° in modern man. In the anthropoids the angle totals 38°. The hominid face, therefore, is directed downward to a greater extent than that of the anthropoids. This difference becomes still more pronounced when the total facial triangle is taken into account (See no. 27).

27. The nasion angle of the total facial triangle—nasion-basion; nasion-gnathion; basion-gnathion—amounts to 56° in *Sinanthropus;* to 63° in *Pithecanthropus* Skull IV; to 56° in the Neanderthalians; to 60° in modern man, and to but 28.5° in the anthropoids. If the terms "pro-, meso- and orthognathism" are also applied to the position of the base of the mandible, *Sinanthropus* and the Neanderthalians are more prognathous in this respect than the anthropoids, but less than *Pithecanthropus* or even than the average in modern man (See no. 30).

28. The basion angle of the total facial angle amounts to 65.5° in *Sinanthropus;* to 70° in *Pithecanthropus;* to 68.5° in the Neanderthalians; to 69° in modern man; but to only 59° in the anthropoids. The hominid face, therefore, is shorter but of greater height than that of the anthropoids.

29. The nasion angle of the nasal triangle—nasion-basion; nasion-nasospinale; basion-nasospinale—amounts to 66° in *Sinanthropus;* to 64° in *Pithecanthropus* Skull IV; to 66° in modern man and to 92° in the anthropoids. The difference between this angle and the nasion angle of the upper facial triangle totals 6° in *Sinanthropus;* 17° in *Pithecanthropus* Skull IV; 1° in modern man and 8° in the anthropoids. The nasospinale generally therefore occupies a more backward position than the prosthion; but in modern man this backward position is less pronounced than in the anthropoids and primitive hominids. Consequently, the reduction of the alveolar process of the maxilla is greater than that of its base (body of the maxilla).

30. The nasion angle of the total facial triangle amounts to 60° in modern man but to only 56° in *Sinanthropus* and the Neanderthalians. (See no. 27.) Therefore the chin region projects more in modern man than in primitive hominids. On the other hand, the angle of

inclination for the entire mandibular front amounts to 84.5° in *Sinanthropus;* to 87° in *Pithecanthropus;* to 93.5° in the anthropoids but to only 76° in modern man. The reduction of the alveolar process is also in the case of the mandible (See no. 27) greater than that of the base of the mandible.

31. The total face of *Sinanthropus* is hypereuryprosop with an index of 79.7. The total facial index of *Pithecanthropus* Skull IV is 78.0 and that of the Neanderthalians 87.9. In modern man the average index of all the races amounts to 88. Compared with the Neanderthalians and modern man, *Sinanthropus* and *Pithecanthropus* have a broader face. In the anthropoids the face is hyperleptoprosop in spite of the considerable bizygomatic breadth.

32. The upper face of *Sinanthropus* is mesen with an index of 52.1. So is that of *Pithecanthropus* with an index of about 50. The Neanderthalians are higher with an index of 58; the index of the Rhodesian skull is still higher amounting to 64.6. This index comes very close to that of the anthropoids, varying around 70.

33. Like the bones of the calvaria (See no. 22) all the bones of the facial skeleton are very massive, much thicker than the corresponding bones in modern man. Where sinuses are present they are larger since they correspond to the greater size of the individual bones but in extent they do not involve more of the skeletal parts than in modern man and, indeed, lag far behind the anthropoids in this matter.

II. SPECIAL FEATURES

1. Calvaria

Frontal bone

34. The contours of the glabellar torus and the supraorbital tori are not rounded but show rather sharply defined surfaces. There is in particular a well developed edge where the superior and anterior surfaces meet. Such an edge is characteristic of the chimpanzee and the gorilla. It is also found in the Rhodesian and Ngandong skulls, whereas the other Neanderthalians show rounded tori.

35. The course of the supraorbital margin is interrupted by a wide but shallow notch which occupies the medial section and is bordered laterally by a distinctly prominent tubercle—tuberculum (processus) supraorbitale. In *Pithecanthropus* this entire region is not preserved. In the Ngandong skulls both features exist but are not as distinct as they are in *Sinanthropus.* They are well developed in the Rhodesian skull but only faintly indicated in the other Neanderthalians except for the Galilee and Skhūl V skulls. In modern man the notch is replaced by a deep and narrow indentation—incisura supraorbitalis—which is occasionally bordered by a slight tubercle-like swelling. In the anthropoids notch as well as tubercle are missing; only sometimes are they faintly indicated in gorilla.

36. There is no supraorbital foramen in *Sinanthropus* either in connection with the supraorbital notch or otherwise. The conditions in the Ngandong skulls are obscure. The Rhodesian and Palestine skulls are like *Sinanthropus.* Other Neanderthalians possess these foramina. They may occur in gorilla but not in the same position as in modern man where they are of frequent occurrence.

37. There is no lacrimal groove in *Sinanthropus* except for the infantile Skull III where its presence corresponds to the age. The lacrimal groove is also absent in *Pithecanthropus* Skull II. In some of the Ngandong skulls there is a groove; in some it is lacking. In the Rhodesian skull a slight depression is recognizable on either orbit and the same is true of the other Neander-

thalians while in others the groove is very distinct. In modern man the groove is well developed. In anthropoids the groove, when it exists, has a different character. On the whole it is a more restricted depression and behind the place where it is found in man. The groove which has also in modern man only topographical relation to the lacrimal gland is always very pronounced in infantile and fetal skulls.

38. A metopic suture is preserved in the adult female Skull XI. This is the first case where the persistence of this suture has been observed in the skull of a fossil hominid. The suture occurs in about six per cent of modern man while it is rare in anthropoids. The occurrence amounts to 2.4 per cent in gorilla; 1.0 per cent in orang-utang but has not so far been found in normal-sized chimpanzee but only in the dwarf type.

39. The foramen caecum seems to be absent as in anthropoids but the frontal crest is well developed. There was apparently a relatively deep olfactory recess as is also characteristic of anthropoids.

40. The endocranial relief is very pronounced and its extent, both laterally and upwards (but particularly in the last direction), is greater than in modern man. It comes to a rather sudden stop just in front of the coronal suture where it seems to be barred by a threshold-like, transverse swelling.

Parietal bone

41. The parietal bone is smaller, flatter, thicker and more rectangular in its outlines than in modern man. The external surface, calculated in square centimeters, covers only about three fifths of the area covered by the parietal bone of a male European. The greater flatness of the *Sinanthropus* parietale is restricted to the two longitudinal margins while the transverse ones are even more curved than in modern man.

42. There is a circumscribed obelion depression in the infantile Skull III. A depression of exactly the same character and at the same place is found in the infantile *Pithecanthropus* Skull III. There is, however, little known as to the occurrence of this feature in other fossil hominids, modern man or anthropoids.

43. The pterion sutures show the typical human pattern but the sphenoparietal suture was apparently very short, not exceeding 3 or 4 mm. in length in Skull XII. In *Pithecanthropus* the pterion region is not preserved. In the Ngandong skulls the conditions are obscure. But so far as a verdict may be rendered, neither seems to have differed from *Sinanthropus*. The same holds true for the Neanderthalians except for the Rhodesian skull which shows the anthropoid pattern.

44. The cerebral surface of the parietal bone is characterized by the formation of granular foveolae close to the sagittal margin and, above all, by the development of a pronounced Sylvian crest. This occupies the entire sphenoid angle, runs obliquely upwards and backwards and fades out before it reaches the center of the bone. In *Pithecanthropus*, the Ngandong skulls and in the Neanderthalians—at least in some of them—the crest exists. In lessening degree, it is found in modern man where it cannot, however, compare in strength with the conditions shown by *Sinanthropus*. As for the anthropoids, this crest can be discerned neither in gorilla nor chimpanzee but it occurs in orang-utang, although in a poorly developed state.

Occipital bone

45. The length-breadth index for the whole squama is very low (74.0 for the chord and 75.6 for the arc). This is much lower than in modern man where the average chord index amounts

to 87.3. The shortness of the squama is characteristic of the anthropoids. In *Pithecanthropus* the chord index is less than 70.0. In the Ngandong skulls it is about the same as in *Sinanthropus*. In the Rhodesian skull it is the same as in *Pithecanthropus:* 69.0.

46. The length chord index of the upper and lower scales totals 123.0, the upper scale being considerably shorter than the lower one. In modern man reversed conditions exist, the average amounting to 62.3. That is to say, the upper scale has here about twice the length of the lower one as compared with *Sinanthropus*. In *Pithecanthropus* the index is little over 100 and so it is in *Homo soloensis*. The Rhodesian skull has an index of 100.

47. The squama is much more curved in *Sinanthropus* than in modern man, the index of curvature being 73.8 in the former and 80.8 in the latter. In *Pithecanthropus* and *Homo soloensis* the index (75.0 and 75.7, respectively) is only a little higher than in *Sinanthropus*.

48. In four of the five preserved *Sinanthropus* skulls, the apex region of the squama is separated from the rest of the occipital plane by accessory, transverse sutures. In two cases there is a sutura mendosa separating almost the entire upper scale. In the two remaining skulls there is a large interparietal bone the height of which is about half the height of the upper scale. Neither *Pithecanthropus* nor the Ngandong skulls show any indication of these supernumerary bones. As for the Neanderthalians, the skull of Saccopastore exhibits a great number of Wormian bones in the lambda region (S. Sergi, 1934) but none of them reaches the size or has the position of the *Sinanthropus* bones. The so-called "Inca bones" or "ossa epactalia" occur in a small percentage of all races of modern man, particularly in the Amerinds, yet they have never been found in anthropoids.

49. The cerebellar fossae are much smaller than the cerebral ones, being about half the size of the latter. In modern man the conditions are reversed, the cerebral fossae occupying only about half the space of the cerebellar fossae. As a result of these conditions in *Sinanthropus* the cruciate eminence lies nearer the occipital foramen and, consequently, much below the level of the center of the occipital torus (inion) than is true in modern man. In the anthropoids, in *Pithecanthropus* and in the Ngandong skulls the conditions are the same as in *Sinanthropus*, and the same seems to be true for most of the Neanderthalians.

Temporal bone
Squama

50. The squama has the form of a right-angled triangle, the parietal margin representing the longer cathetus and the sphenoid margin the shorter one. This form is very characteristic of the anthropoids. In modern man the parietal margin forms a high curve the vertex of which usually lies vertically above the mandibular fossa. Only the Eskimo show the triangular pattern of *Sinanthropus*. *Pithecanthropus* and *Homo soloensis* resemble *Sinanthropus* while the Neanderthalians show the pattern of modern man, some of them in a pronounced fashion.

51. The squama is very low in proportion to its length, its length-height index averaging 49.6. In modern man the index is 65.2 while in the anthropoids it varies from 25.0 to 43.0. *Pithecanthropus* and *Homo soloensis* are like *Sinanthropus* in this matter while the Neanderthalians resemble modern man.

52. There is a deep, distinct parietal notch of acute angularity which separates the squama from the mastoid portion. This notch is less developed in *Pithecanthropus* but very pronounced in the Ngandong skulls and in the Neanderthalians. In modern man there is great variability in the notch, regardless of race. The notch is wanting in chimpanzee and gorilla but always present in orang-utang.

53. The zygomatic process continues as a strong, projecting supramastoid crest while the process itself is held away from the squama by a wide, shallow "sulcus processus zygomatici." These are characteristic features of the anthropoids. On the contrary, in modern man, although the crest varies in strength, it never reaches the degree of development presented in *Sinanthropus* while the sulcus appears deep and narrow. *Pithecanthropus* and *Homo solensis* resemble *Sinanthropus*. The Neanderthalians, although they differ as regards the crest, never show any development so great as that of *Sinanthropus* while the sulcus is wider and shallower than that of modern man.

54. There is no true articular tubercle in *Sinanthropus* but its place is taken by a "planum preglenoidale." The mandibular fossa, compared with that of modern man, gives the impression of being very deep due, apparently, to the short distance it extends in the sagittal direction. In the anthropoids there is neither an articular tubercle nor a true mandibular fossa. *Pithecanthropus* shows the *Sinanthropus* pattern. *Homo soloensis* has a tubercle and a deep and narrow fossa. The Neanderthalians do not show any essential deviation from the conditions of modern man. The difference between the hominids and anthropoids in regard to the articular region is not that suggested by most authors. The hominids do not develop a tubercle as has been suggested: On the contrary, it is the anthropoids in which the mandibular fossa disappears. The infantile anthropoids have a real fossa which vanishes as their age increases. On the other hand, the deep hominid fossa is without any functional value, since the articular disc levels the differences in height between fossa and tuberculum or planum preglenoidale; the thicker the fossa portion of the disc the deeper the fossa and vice versa. In the anthropoids the disc is thin and its fossa and tubercular portions are of the same thickness.

55. The mandibular fossa develops a medial recess that extends between the tympanic plate and the entoglenoidal process (see under no. 57). The medial wall of the fossa, therefore, does not appear to be concave but convex and bulging into the fossa. This peculiarity, or at least one based on the same principle, is found in anthropoids as well as in modern man. The only difference is that, in the latter, the recess looks more like a narrow fissure which separates the tympanic from the adjacent squama and sphenoid, respectively.

56. The center of the mandibular fossa coincides with the cerebral surface of the cranial wall above the fossa. In modern man the mandibular fossa underlies the lateral part of the middle cranial fossa. In the anthropoids the greater part of the mandibular fossa has shifted laterally to the root of the zygomatic process, a condition which the gorilla shows in a pronounced manner. These mutual changes in position are the consequences, apparently, of the lateral expansion of the hominid vault. *Pithecanthropus* and the Ngandong skulls show the *Sinanthropus* pattern but the Neanderthalians exhibit more that of modern man.

57. There is not a true postglenoid process as there is in gorilla or orang-utang, but there is a low, broad-based, transverse elevation marking the boundary between the lateral moiety of the mandibular fossa and the "tegmen pori acustici" (see no. 60). The postglenoid elevation must be regarded as the remains of a strong barrier-like structure which has lost its importance as the tympanic has taken over its functions. *Pithecanthropus* and *Homo soloensis* are like *Sinanthropus* while the Rhodesian skull possesses a well developed postglenoid process. As for the remaining Neanderthals, the process is lacking in the Spy skulls; pronounced in, at least, one of the Krapina fragments; moderately developed in the Mount Carmel skulls. In modern man there is much variability but there can be no doubt that the process is here bigger than in early hominids.

58. The "entoglenoidal process" which forms the medial wall of the mandibular fossa does not represent a true process but a steep slope entirely built by the squama. In modern man a process exists. The sphenoid usually takes part in its formation by developing a spine which descends below the level of the laterally adjacent squama of the temporal bone. But there are cases in which no spine exists and the wall is formed by the squama alone as in *Sinanthropus*. In the anthropoids there is also a crest-like process formed by the squama or by the squama and sphenoid in equal parts. In *Pithecanthropus* the conditions are obscure; *Homo soloensis* shows the *Sinanthropus* pattern; and the Neanderthalians exhibit the type of modern man.

59. The cerebral surface of the squama is very low but relatively long. This lowness is due, to some extent, to the lowness of the whole squama but it is due, to a far greater extent, to the extraordinary breadth of the squamous suture. This considerably diminishes the height of the inner surface when compared with the outer one. The suture is 22 mm. at its widest point and 14 mm. at its narrowest, whereas in modern man the corresponding measurements are 15 mm. and 6 mm. respectively. The low aspect is further emphasized by the bulging of the sylvian crest (See no. 44). This occupies the sphenoid angle of the cerebral surface of the parietal bone and, therefore, the upper limit of the medial cerebral fossa. So far as it is possible to discern, the conditions are the same in *Pithecanthropus* and *Homo soloensis*. In the Neanderthalians however they come close to the conditions shown by modern man, except for the development of the Sylvian crest. The anthropoids resemble *Pithecanthropus* in these features but possess no Sylvian crest.

Tympanic plate

60. The tympanic plate differs from that of modern man in form, position and thickness. With reference to the auriculare, the tympanic of *Sinanthropus* lies in a so much more medial position that the zygomatic process forms a roof which widely overhangs the porus—tegmen pori acustici. The same conditions exist in *Pithecanthropus* and in *Homo soloensis*. As for the Neanderthalians, the tegmen is well developed in the Rhodesian and Spy skulls but missing or less developed in the skulls of La Chapelle, Krapina, Ehringsdorf and Mount Carmel. Of the anthropoids, only the orang-utang has an overhanging roof while in gorilla the tympanic may even overlap the auriculare.

61. On the whole the tympanic plate is oriented more horizontally than it is in modern man. That is to say, in *Sinanthropus* the bone lies parallel to the basal surface of the skull while in modern man it assumes a more frontal position. *Pithecanthropus* and *Homo soloensis* are like *Sinanthropus* as are the anthropoids, while the Neanderthalians exhibit more nearly the character of modern man (cf. also no. 68).

62. The axis of the tympanic plate forms almost a right angle to the mid-sagittal line. In modern man the angle is acute, the medial border of the plate being situated on a more anterior level than that of the lateral one. *Pithecanthropus* and *Homo soloensis* show the same orientation as *Sinanthropus* whereas the Neanderthalians are more like modern man. In the anthropoids the right angle exists in gorilla and chimpanzee while the orang-utang tends toward an acute one.

63. The part of the tympanic plate which forms the posterior wall of the mandibular fossa is either plane or more or less convex where it is concave in modern man. This divergence seems to be caused by the difference in the thickness of the bone. In *Sinanthropus* the plate is very thick in agreement with the general thickness of the cranial bones. In modern man, however,

the plate is so thin, especially in the center of the wall, that it may be perforated in individuals of advanced age. Only the lateral margin of the plate which forms the edge of the auditory porus retains its original robustness. This occurs almost regularly in Eskimo skulls where it appears as a general "exostosis" of the porus (cf. no. 66). *Pithecanthropus* and *Homo soloensis* follow the *Sinanthropus* pattern while the Neanderthalians show that of modern man save that the "exostosis" is reminiscent of the original conditions. In anthropoids the plate is thicker than in modern man but it does not reach the *Sinanthropus* dimensions save in the region of the edge.

64. The transverse slit which divides the porus edge and the entire lateral moiety of the tympanic into an anterior and a posterior portion is shown only in Skull III and is an infantile character. The infantile skulls of modern man have such a slit or more commonly a hole. The hole may even persist throughout life. Since in modern man the plate is much thinner than in *Sinanthropus*, slit and hole look like an erosion or artificial perforation—"Huschke's foramen." It seems that the Mongols retain this fetal character more than other races. This may also be the case in *Sinanthropus*. The conditions in other fossil hominids are not known.

65. The auditory aperture is relatively wide and varies in its form, although a horizontally oriented, eliptic form prevails. In modern man the aperture is wide and the vertically eliptic form the more frequent, although the width, in no case, reaches that of *Sinanthropus*. The two *Pithecanthropus* skulls available for these observations (II and IV) show the same variability. The aperture of Skull II is horizontally elliptic, that of Skull IV vertically elliptic. In the Ngandong skulls the aperture is wide and horizontally elliptic. In the Neanderthalians both types are found but the horizontal orientation seems to prevail. In the anthropoids there is a striking difference between gorilla and chimpanzee, on one hand, and orang-utang, on the other. In all three types the aperture is small in relation to the size of the entire skull but proportionate to the size of the braincase. In gorilla and chimpanzee the aperture is almost completely round and without any special inclination either to the horizontal or the vertical. In the orang-utang, however, a horizontally eliptic form is markedly predominant.

66. In *Sinanthropus* Skull X there is a circumscribed "ear exostosis" located on the anterior border of the tympanic which extends from the porus 14.5 mm. inward into the meatus. Exostoses of the same form and location occur in modern man but they are restricted to certain racial groups, especially the Mongols. So far no exostoses of this kind have been found in fossil hominids nor have they been described in anthropoids.

Petrous portion

67. Because of its more horizontal position the tympanic plate covers the lateral portion of the pyramid base to a greater extent than is the case in modern man. In man the exposed parts, particularly the apex region of the pyramid, appear as if the bone were eroded and rarified, and the bony substance between the various canals reduced to membrane-thin partitions while in *Sinanthropus* the bone is solid and its surface smooth and even. The pyramid of *Pithecanthropus* and *Homo soloensis* has the same character as that of *Sinanthropus* whereas the Neanderthalians exhibit more of the human type. The anthropoids, with the orang-utang differing slightly from the general rule, display the conditions existing in *Sinanthropus* in a still more pronounced manner.

68. An axial line drawn through the base of the tympanic plate and pyramid is not straight as it is in modern man. The axis of the tympanic plate runs in transverse direction (cf. no. 61)

while that of the uncovered part of the pyramid curves obliquely forward. The two lines form an obtuse angle the corner of which falls on the entrance to the carotid canal. In the anthropoids this angle is very pronounced in gorilla and chimpanzee and to a somewhat less extent in the orang-utang. *Pithecanthropus* and *Homo soloensis* exhibit the *Sinanthropus* angle whereas the Neanderthalians show the conditions of the modern human type. In man this axis-line is sometimes not completely straight but rather like that of the orang-utang slightly curved.

The bend of the axis is mainly due to a change in the direction of the pyramid. Its axis forms an angle of about 15° with the mid-sagittal line while the deviations amount to 40° in *Sinanthropus* and over 60° in modern man. The tympanic plate is transversely orientated in *Sinanthropus* and the anthropoids. In man it moves more and more in line with the pyramid axis. These changes go hand in hand with changes in size, in robustness and especially in length which involve both tympanic plate and pyramid (cf. nos. 63 and 67).

69. Due to the more vertical orientation of the tympanic plate and the frailness of its bone, its lower margin forms a thin crest in modern man. Midway between the porus and carotid canal, this crest develops here a spine-like projection against which the styloid process leans. In *Sinanthropus* both crest and spine are quite massive structures. This is particularly true of the spine which has more the appearance of a broad-based pyramid and is situated more medially than in man. *Pithecanthropus* and *Homo soloensis* are like *Sinanthropus* while the Neanderthalians are like modern man. In anthropoids the crest appears as a low, rounded ridge while the spine rises in a more median position at the end of the ridge, lateral to and behind the carotid canal.

70. The styloid process is entirely lacking in *Sinanthropus* and so is the vaginal process. In some specimens there is a small foramen posterior to and at the end of the spine. To this foramen a narrow groove runs down from the spine. In modern man styloid and vaginal processes are normal features. The latter is always present. The former, however, may be wanting or it may be represented merely by a short, fine piece of bone as is frequently the case in Australian aborigines. In *Pithecanthropus* the region in question is damaged. In the Ngandong skulls the styloid process is missing but it seems that the vaginal process was developed. The latter conditions may have also existed in the Rhodesian skull while the remaining Neanderthalians show well formed styloid and vaginal processes. In anthropoids the styloid process is as a rule lacking. Among orang-utangs and chimpanzees of more advanced age this is not always true. In such individuals there may sometimes be found a small bone protruding from a hole behind the base of the petrous spine. Gorilla has only the hole, and no anthropoid has developed a vaginal process.

71. There is a distinct swelling, a "processus supratubalis" which marks the medial-anterior end of the tympanic plate and bounds, from above, the entrance to the canalis musculo-tubarius. In modern man this is restricted to a fine spine-like projection which represents the termination of the petrous crest whereas the anthropoids have a big protuberance which projects far and ends in a sharp point. In *Pithecanthropus* this region is not preserved but it seems that the process was developed in *Homo soloensis*. The Rhodesian skull also reveals a tubercle-like elevation above the entrance to the canal.

72. The carotid canal seems smaller than in modern man. This is certainly the case with the jugular fossa which is flatter, narrower and shorter than is the rule in man. The anthropoids have very narrow canals for artery and vein. In *Pithecanthropus* the region is damaged. *Homo soloensis* shows the same conditions as *Sinanthropus* and so does the Rhodesian skull and some of the Neanderthalians.

Mastoid portion

73. The mastoid portion, as in modern man, consists of two parts; an anterior, protruding one and a posterior, flat one. The former extends further back than in the average man and, in addition, appears rather as a lateral bulge of the cranial wall itself than as an independent process with a downward trend as shown in man. As regards the mastoid process in anthropoids, the three apes exhibit different conditions. In orang-utang and chimpanzee there is no distinct mastoid process. The entire region bulges while only a part of the surface-area is roughened, recalling the conditions of the mastoid process in man. In gorilla the same conditions prevail except that a portion of the roughened surface projects downward, giving the appearance of a small mammillary process.

The mammillary process of the mastoid is relatively small in all the *Sinanthropus* skulls, the smallest being found in female Skull XI and juvenile Skull III. In the remaining skulls the exposed base is large and triangular in form. In modern man there is great variability. In most cases the process looks as if the median half were cut off, an appearance due to the presence of a deep and narrow groove, the incisura mastoidea (so-called digastric fossa). As for the anthropoids, the gorilla exhibits a small, barely projecting, free portion.

The conditions of the mastoid region in *Pithecanthropus* are the same as in *Sinanthropus*. The female Skull II has a very small free portion but the male Skull IV does not differ from a modern man with a large process. The process is also large in the Ngandong skulls, not lagging far behind modern man in its dimensions. Except for the Rhodesian skull, the mastoid process is small in the Neanderthalians.

74. The supramastoid and mastoid crests and the sulcus between are well developed in *Sinanthropus*. Both crests are part of the post-otic ring system which builds the basal architectonic framework of the calvaria (cf. no. 20). The crests and the sulcus occur in all hominid skulls but they are much less pronounced in modern man than in earlier stages. In anthropoids there is only one crest which appears to be connected with the nuchal crest. The nuchal crest, however, is not identical with the post-otic ring system of the hominids.

75. The suprameatal spine is missing. In only three out of eight cases there is an unevenness of the surface of the bone occupying the usual site of the spine which perhaps indicates a vestige of that formation. A distinct spine is also wanting in *Pithecanthropus* and *Homo soloensis* while it is well developed in the Neanderthalians. In modern man the spine is absent in a little more than 10 per cent regardless of race. In anthropoids there is no spine but there are irregular excrescences, particularly in gorilla and orang-utang, which may be equivalent to it.

76. The incisura mastoidea varies in form and size. In some of the cases it is very wide and shallow; in others it is deep and narrow as it is usually found in modern man. In *Pithecanthropus* Skulls II and IV the notch is wide and shallow. In the Neanderthalians, including the Rhodesian skull, it is deep and narrow as it is in modern man. In anthropoids there is a broad, smooth impression medial to the mastoid tuberosity. This is most pronounced in gorilla and least in orang-utang.

77. The occipitomastoid suture runs along a relatively high crest which marks the joined margins of the temporal and occipital bones. This occipitomastoid crest seems—so far as the deficiency of the skulls allows a verdict—less pronounced or missing in *Pithecanthropus* and *Homo soloensis*. The crest is well developed in the Rhodesian skull. In the other Neanderthalians, the region in question is not preserved or is damaged or obscure. In modern man the crest occasionally occurs as a demarcation of the mastoid notch. In the anthropoids it marks the

median border of the mastoid tuberosity and varies in the degree of its development according to the individual and type.

78. The pyramid, if looked at from inside the skull, appears as a stout, relatively flat structure of large dimensions with the superior margin presenting an obtuse or rounded corner and the two surfaces pressed down against the floor. The height of the posterior surface of the pyramid, measured at its base, amounts, therefore, to not more than 18 mm. even in the biggest specimens while it reaches 23 mm. or more in modern man. In man the whole pyramid is smaller and more pinched in longitudinal direction. Accordingly the relief of the anterior and posterior surfaces stands out more distinctly in modern man than in *Sinanthropus*. In the anthropoids the characteristics of the *Sinanthropus* pyramid are still more pronounced. *Pithecanthropus*, particularly in Skull IV, resembles *Sinanthropus* and so does *Homo soloensis* while nothing is known about the conditions in the Neanderthalians.

79. The sulcus sigmoideus, in continuing the conditions of the sulcus transversus, is much shallower and narrower, particularly shallower, in the skull of *Sinanthropus* than in that of modern man: also the anthropoids have relatively narrow and shallow sulci. *Pithecanthropus* shows the same conditions as *Sinanthropus*. There is nothing known about the dimensions of the sulci in the Neanderthalians.

As in anthropoids the sigmoid sulcus does not encroach on the mastoid angle of the parietal bone as it is often found in modern man.

80. The lateral section of the medial cerebral fossa which lodges the temporal lobe is relatively longer but much lower in *Sinanthropus* than in modern man. This is chiefly due to the lowness of that part of the fossa which falls on the squama but also to the strong development of the sylvian crest (See no. 44). The same conditions seem to exist in *Pithecanthropus* and, among the Neanderthalians, in the Rhodesian skull. In the anthropoids the fossa seems much wider in proportion to the entire cranial cavity since the Sylvian crest is missing.

Sphenoid bone

81. The facies temporalis passes gradually over to the facies infratemporalis so that both surfaces present a continuous curve without the sharp bend or strongly developed infratemporal crest which usually characterizes modern man. In *Pithecanthropus* and *Homo soloensis* this region is not preserved. In the Neanderthalians there is great variability. The Rhodesian, Gibraltar and Steinheim skulls show a sharp bend and well developed crest while the Ehringsdorf skull exhibits the *Sinanthropus*-pattern. As to the anthropoids, the modern human type predominates in chimpanzee; the *Sinanthropus* type is characteristic of gorilla and orang-utang.

82. The facies temporalis comes down to the maxilla rather closely so that the orbital fissure is reduced to a mere slit and the orbit only accessible from below. In modern man the facies usually terminates at a higher point so that the fissure appears as a more widely open cleft and the orbit becomes accessible directly from the side. In the anthropoids the fossa temporalis considerably overlaps the corner where the orbital and temporal facies of the maxilla meet. Thus the fissure appears as a narrow slit and the orbit is accessible only from below. *Pithecanthropus* and the Ngandong skulls are defective in this region. The Rhodesian skull resembles *Sinanthropus* and, so far as can be determined from casts and photographs, this is true of all Neanderthal skulls (cf. also no. 118).

83. The facies cerebralis is very small in transverse direction, the transverse arc amounting to only about four-fifths of that of modern man. In addition, the facies is low and looks, there-

fore, like a small niche without exhibiting any special relief.   In modern man the facies is widely curved and occupies a much larger area in transverse as well as in vertical direction.   In the anthropoids the facies cerebralis is very small and restricted in the floor of the medial cerebral fossa.   As to the Neanderthalians, the Rhodesian and Ehringsdorf skulls resemble *Sinanthropus* while the Gibraltar and Galilee skulls modern man.

84.   The greater wing is very robust; the edge of the margo squamosus between facies temporalis and cerebralis, for example, is about 8 mm. thick while it scarcely reaches a thickness of 1 mm. in man.   Among the anthropoids the orang-utang comes closest to Sinanthropus. Conditions among the other hominids are not known.

2.   Face

Nose

85.   The nasofrontal suture, together with the frontomaxillar suture takes a continuous, horizontal course.   In modern man such a course is found in Mongols and Negroes while in Europeans the suture tends to ascend toward the midline or is interrupted by the nasal bones which may extend farther upward than the frontal process of the maxilla.   The Rhodesian skull resembles *Sinanthropus*.   The European Neanderthalians show the pattern of European modern man.   In all three anthropoids the suture ascends toward the mid-line in a much more pronounced manner than in man.

86.   The nasal bones are much wider than those of modern man; even the least width amounts to double the average of modern man.   The Neanderthalians also have wide nasal bones; Krapina man even exceeds *Sinanthropus* in this respect.   In addition, there is practically no difference between the upper and the least width in *Sinanthropus*.   "Broad nasal bones with small differences between upper and middle breadths are most frequently found among Mongols" (R. Martin, 1928).   Anthropoid nasal bones differ widely in form and proportions from those of *Sinanthropus* with the exception of those of the chimpanzee which show some resemblance.

87.   The transverse saddle arc is broad and relatively high, the nasal bones and the bridge portions of the frontal process of the maxilla forming a continuous, curved line.   The height-breadth index amounts to 37.0.   In modern man there is great variability in the conformation and height of the nasal bridge.   The profile contour of the *Sinanthropus* saddle agrees closest with those of the Amerindians, Eskimos and Australian aborigines.   Among the Neander-thalians, the Rhodesian skull comes very close to *Sinanthropus*.

88.   The probable angle of the nasal roof amounts to 89° when FH is taken as base.   This value lies within the range of modern man which varies from 43° to 76°.   An angle of 89° is little above the average of the Mongol racial groups which varies from 66.4° to 68.3°.   The profile angle of the Rhodesian skull totals 73°.   The average of the anthropoids is 67°, but the chimpanzee attains 87°.

89.   The nasal index amounts to 57.2.   *Sinanthropus* is, therefore, chamaerrhine but very close to hyperchamaerrhine.   Among the racial groups of modern man Tasmanian (57.4), Kaffir and Nubian show nearly the same average.   The index of the piriform aperture totals 90.8 in *Sinanthropus*, the average of the Australian is more than 100 as is the average of the negro, while the index of Europeans totals only 70.   In the Neanderthalians, the average nasal index is 55.7 and the aperture index of the Rhodesian skull is 97.3.   The average nasal index of the anthropoids amounts to 41 with the range from 25 to 57.

90. A vertical drawn from the rhinion falls in front of the nasopinale as is the case in the majority of modern man. But in the lower moiety of the aperture the crista nasalis runs forward continuously and meets the floor of the nose in so acute an angle as to equal the conditions of the chimpanzee. In modern man the crista takes a vertical course or even a backward one. The Neanderthalians, including the Rhodesian skull, are like modern man.

91. The nasal floor is even and separated from the clivus nasoalveolaris by a simple margo limitans. There is neither a crest-like sill nor a prenasal groove. The anterior nasal spine is missing. In modern man the crista nasalis usually bends medially and, forming a high sill, runs up to the midline where it terminates with a projecting spine. In the anthropoids there are characteristic differences between orang-utang, gorilla and chimpanzee. In orang-utang there is practically no demarcation between nasal floor and clivus. In gorilla there is a broad and blunt elevation which drops posteriorily more or less abruptly toward the nasal floor while anteriorly it continues into a large prenasal groove. In chimpanzee there is only a margo limitans and either an even or slightly depressed floor behind while the prenasal groove is lacking. As to the spine, it is indicated by a low but distinct elevation in the midline in chimpanzee and, less frequently, in orang-utang. In man also, this elevation may be absent. *Pithecanthropus* Skull IV is like *Sinanthropus* in all these features save that it has a well developed, crist-like spine. All the Neanderthalians possess a well-developed spine and most of them a sill with or without prenasal groove.

Maxilla

92. The facies anterior and the alveolar process of the maxilla is well filled out. There is a broad and prominent "jugum alveolare" at the canine. This extends far upward, borders the apertura piriformis and is separated from the broad and prominent root of the zygomatic process by a narrow "sulcus infraorbitalis." In modern man the whole region is sunken, the canine-jugum being reduced to a narrow ridge. This ridge scarcely reaches beyond the alveolar process; the root of the zygomatic process appears flat or even receding while the sulcus is widened to a more or less developed "fossa canina." In anthropoids the conditions are the same, generally speaking, as in *Sinanthropus* but the canine-jugum is more pronounced and the sulcus correspondingly broadened. The only difference in the three anthropoids is that chimpanzee seems closest to *Sinanthropus*. This is apparently caused by the fact that maxilla and teeth are smaller in all dimensions than those of gorilla and orang-utang. None of the Neanderthalians, including the Rhodesian skull, show such a big canine-jugum nor such a well-developed infraorbital sulcus as *Sinanthropus*. The surface of the maxilla is not sunken to such an extent as in modern man but is less filled out than in *Sinanthropus*.

93. There is a broadly based and rounded malar pillar, the lateral contour of which ascends to form a narrow arch—incisura malaris—before reaching the zygomatic bone. In modern man the pillar usually has the appearance of an edge. The malar notch either has the same character as in *Sinanthropus* or the curve is flatter. In the gorilla and chimpanzee the pillar is edged and the contour continues almost as a straight line into the lower border of the zygomatic arc. In orang-utang there is a more or less pronounced notch as in *Sinanthropus*. The contour-line is straight in all Neanderthalians and a faint notch is indicated only when the malar tubercle projects downward.

94. The clivus nasoalveolaris, as a whole and apart from the alveolar juga, is convex. In modern man it is flat or even concave, regardless of the degree of prognathism, and this is also true of the Neanderthalians. The anthropoids have a convex clivus.

95. There are typical buccal maxillar exostoses extending over the entire molar region. These exostoses are found in all the specimens available and are, therefore, much more frequent than in modern man where they are present in not more than six per cent. In the anthropoids the exostoses seem to be absent. The Rhodesian skull exhibits exostoses but whether they are "normal" or rather the result of alveolar pyorrhea is hard to decide. Their occurrence in other forms of the Neanderthalian group is not recorded.

96. The *Sinanthropus* skull is dolichuranic, the maxilloalveolar index amounting to 107.6. The various racial groups of modern mankind range from 108.2 to 126.0 and the anthropoids range from 52 to 106. The alveolar arch of *Sinanthropus*, therefore, is wider in its span than that of any anthropoid but it does not reach the width of modern man. The average index of the Neanderthalians is the same as that of *Sinanthropus*, but the Rhodesian skull falls within the human range in this matter. In the reconstructed *Pithecanthropus* IV the index totals 120.0; but even conceding the width of the original maxilla to have been smaller, *Pithecanthropus* would not differ greatly from *Sinanthropus* or from the Rhodesian skull.

Palate

97. The palatal surface is rough, the ruggedness being caused by irregular crests, depressed areoles and by fine, more or less longitudinal ridges. *Sinanthropus* does not differ in this respect from modern man. In anthropoids the surface is almost completely smooth. *Pithecanthropus* IV reveals an absolutely smooth palate, too. The Neanderthalians show the modern human pattern.

98. The palatal orifice of the incisive canal lies farther back from the orale than in modern man and the direction of the canal is more oblique than in the latter. In the anthropoids both features are still more pronounced. *Pithecanthropus* IV shares the simian pattern in a striking manner while nothing is known about these conditions in the Neanderthalians.

99. The *Sinanthropus* skull is leptostaphyline, the palatal index amounting to 75.0. Such a value is within the range of modern man—63.0 to 94.6. The anthropoids have much lower indices ranging from 34.5 to 62.5. The Neanderthalians have an average index of 80. The general form of the *Sinanthropus* palate, therefore, is human-like, corresponding to the form of its alveolar arch (see no. 96).

100. The palatal height index amounts to 30.7. This is about the same as the average of modern man. The Neanderthalians (only two measurements are available) have a higher index: 39.7. In anthropoids the average is 46.

Malar region

101. The zygomatic bone is very high. The height in the male individuals can be estimated as amounting to 65 mm. In the reconstructed female skull the height is 50 mm. The maximum height of the modern human bone does not exceed 60 mm., the highest values being found among the Mongolian groups. Among the Neanderthalians, the Rhodesian skull has the highest zygomatic bone (54 mm.). Gorilla and orang-utang possess very high zygomatic bones, the chimpanzee much lower ones.

102. The facies malaris is oriented in a frontal direction. Such an orientation is also found in modern man, but it is peculiar to the Mongolian racial groups. The frontal direction is best demonstrated when malar region and zygomatic arch are viewed from the base. In

Sinanthropus and Mongols alike the contour first runs in a frontal plane, then bends backward in a moderate curve. In contrast, the non-Mongolian races have the entire zygomatic arch facing in a lateral direction with the turning point falling at the maxilla. None of the Neanderthal skulls shows such a pronounced frontal orientation as *Sinanthropus*. In the Rhodesian skull, in spite of the great breadth of the face, the entire lower margin of the zygomatic arch retreats at the zygomaticomaxillar suture. In the anthropoids, the gorilla shows the most pronounced frontal orientation, next comes orang-utang, while in chimpanzee the entire arch faces laterally.

103. The frontal direction of the malar facies (no. 102) includes the frontosphenoidal process of the zygomatic bone. The angle of inclination of the malar facies of the process toward the midsagittal plane amounts to 50° in *Sinanthropus*. In modern man there is a variation ranging from about 25° to 60°, the facies swinging in a frontal direction the more the angle increases. The higher values are characteristic of the Mongolian racial groups. The Neanderthals all show the non-Mongolian type. For example, in the Rhodesian skull the angle is one of only 29°. As for the anthropoids, in gorilla and chimpanzee the facies is turned in a forword direction far more than in man. Only gorilla with an angle of about 50° comes close to *Sinanthropus*.

104. In addition to the frontal orientation (see No. 102), the malar facies is oriented in a rather vertical direction. The angle of the malar profile amounts to 106°. In modern man the angle ranges from 108.8° (Buriats) to 120.2° (Europeans). In anthropoids the angle is in general more acute, ranging from 67° to 110°. The size of the angle depends to a great extent on the vertical inclination of the orbit entrance (see no. 111).

105. There is a well developed "processus marginalis" at the temporal edge of the frontosphenoid process of the zygomatic bone. This process occurs occasionally in modern man, seeming more frequent and more pronounced in Mongolian racial groups than in others. None of the Neanderthalians, including the Rhodesian skull, have the process developed. What is called "process" is in reality not a projection of the edge but is caused by a contraction of the orbital frame above it. This contraction coincides with the zygomaticofrontal suture and should be called "incisura zygomaticofrontalis." Occasionally there is also an indentation below the "process" where the temporal border of the frontosphenoidal process meets the temporal process of the zygomatic bone—"incisura zygomaticotemporalis." There is no such differentiation in gorilla or chimpanzee but a well-developed one in orang-utang.

106. The zygomatic arch runs below the level of the Frankfort Horizontal. In modern man it runs parallel to the Horizontal keeping the same level while in anthropoids it descends still more from its root than it does in *Sinanthropus*. The Neanderthalians show no deviation from the pattern exhibited by modern man. Even the Rhodesian skull, in spite of the bulkiness of the maxilla, is like modern man.

Orbit and orbital region

107. The orbital index amounts to 81.9 or to 90.0 when the lacrimale is used as landmark for the width measurement. *Sinanthropus* is, therefore, chamaeconch or even hypsiconch in spite of his heavy supraorbitals. Among the races of modern man Kalmucks, Burmese and Battak have the same index. In anthropoids the index is much higher, the average reaching 101; only the chimpanzee is mesoconch with a minimum index value of 76. In the Neanderthalians the index ranges from 65.3 to 84.8 with an average of 76.7. That is to say, all types of orbits,

from chamaeconch to hypsiconch, are represented in this hominid group, although the prevailing **type** is the mesoconch one—close to its lower limit.

108. The cephalo-orbital index amounts to 7.3. The average of all races of modern man **is 4.2.** That of anthropoids is 14.2. The difference between man and the anthropoids is mainly **due** to the large cranial capacity of the former. In *Sinanthropus* the cranial capacity is less than **in** modern man but much greater than in anthropoids. Therefore, its cephalo-orbital index is **higher** than that of modern man but below that of anthropoids. As for the Neanderthalians, **La** Chapelle-aux-Saints with an index of 4.7 falls within the range of modern man while the Rhodesian skull (6.5) comes close to *Sinanthropus*

109. The interorbital index is 22.5. This falls just beyond the upper end of the range of modern man which varies from 18.2 to 22.2, so far as entire racial groups are concerned. The interorbital index of anthropoids shows a much greater variability, ranging from 13.3 to 37.0 with orang-utang at the lower and gorilla at the upper end of the line. Among the Neanderthalians, the Rhodesian skull has the same index as *Sinanthropus* (22.8) while the others show a higher index, raching up to 31.8 in the case of Tabūn I.

110. The angle of the orbital axes totals 52°. This is a little larger than the greatest individual angle, that of Japanese which is 51°, the average of European and Japanese together being 41°. In anthropoids the angle varies from 30° (orang-utang) to 40 (chimpanzee). No measures are available for Neanderthalians; the angle of the Rhodesian skull may be the same as that of *Sinanthropus*.

111. The angle of vertical inclination of the orbit amounts to 110°. The maximum value of this angle in modern man is 105° with a range from 81° to 105°. In anthropoids the angle is much smaller, varying from 55° to 93°. In the Neanderthalians the angle varies from 103° to 109°. The angle of the *Sinanthropus* orbit is greater than that of any other hominid or of any anthropoid. In the latter the small angle is caused by the prominence of the infraorbital margin, a consequence of the pronounced prognathism of the anthropoid maxilla. In hominids the angle is great because of the orthognathism of the human maxilla. *Sinanthropus* shows the human pattern in the reduction of the maxilla but exaggerates this by retaining the heavy supraorbitals (see also no. 104).

112. The angle of frontal inclination for the orbit amounts to 11° while the average of modern man is 17.5° with a range from 9° to 28°. In anthropoids the angle equals 0°, rising in chimpanzee and gorilla to 5°. The angle decreases more and more as the lateral border of the orbit comes in line with the medial one; or, in other words, the "flatter" the face. In modern man the angle is smallest in Mongolian racial groups. *Sinanthropus* is very close to the minimum value of modern man. In the Rhodesian skull the angle amounts to 7°.

113. The angle of horizontal inclination of the orbit is 10°. The average of modern man amounts to 12.6°. In anthropoids the angle is close to 0°. *Sinanthropus*, therefore, shows the human pattern.

114. Of the four walls of the orbit only the superior one is longer than that of modern man. Its length is 57 mm. or 63.5 mm., depending upon what point is taken as the anterior terminus of the midline of the roof (see no. 115). The average length in modern man is 50 mm. The great projection of the supraorbitals is responsible for the exceeding length in *Sinanthropus*. According to Sir Arthur Keith (1927), the length in the Rhodesian and La Chapelle skulls is 65 mm., and 63 mm. in the Gibraltar skull.

115.   The supraorbital margo is a thick, rounded structure the anterior surface of which continues without distinct demarcation into the slightly vaulted roof of the orbit.   In modern man the margo represents an edged crest which descends from the well-vaulted roof.   In anthropoids the conditions are the same as in *Sinanthropus* with the exception that in the female orangutang an edged margo and a vaulted roof occur.   *Pithecanthropus* and *Homo soloensis* are like *Sinanthropus* and the same holds true for the Rhodesian skull.   The other Neanderthalians show, more or less, the conditions of modern man.   (For other features concerning the supraorbital margin see (nos. 34–37).

116.   The infraorbital margin is rounded and is at the same level as the even floor of the orbit.   In modern man an edged or rounded margin occurs but the floor behind the margin declines, so that there is a more or less deep groove medially and in front of the anterior end of the inferior fissure.   A rounded margin and an even floor are very common in Mongolian skulls. Among the anthropoids, in the male gorilla the same combination is frequent; in all three types the margin is rounded but the development of the groove varies and the floor may be either even or deepened.   The Rhodesian skull shows the same conditions as *Sinanthropus*.

117.   The superior fissure is reduced to a small, almost circular hole probably not much larger than the optic foramen.   In modern man the fissure consists of a larger central portion and a slit-like lateral prolongation varying in length and width.   In anthropoids, gorilla has a small, circular fissure without lateral prolongation.   The same occurs in orang-utang and chimpanzee but there may have developed a short, lateral prolongation.   The Rhodesian skull is like *Sinanthropus*.

118.   The inferior fissure was probably a narrow slit which opened downward into the infratemporal fossa (see no. 82).   In modern man width and length of the fissure vary considerably. If the fissure is wide the orbit communicates horizontally with the infratemporal fossa.   In all anthropoids there is a narrow slit with a downward direction.   The Rhodesian and Steinheim skull show the same conditions as *Sinanthropus*.

119.   The foramen zygomatico-orbitale inferius is a relatively wide, funnel-like orifice situated where the floor ascends toward the lateral wall and in immediate continuation of the lower fissure.   In modern man the foramen is smaller, looking rather like a puncture with a forward direction.   It lies at the ascending portion of the lateral wall.   Anthropoids vary. The foramen is lacking or extremely small in gorilla but usually very wide in orang-utang and chimpanzee.   While it is high up at the lateral wall in orang-utang, in chimpanzee it is occasionally found at the same place as in *Sinanthropus*.   Among the Neanderthalians, the Rhodesian skull shows the same conditions as *Sinanthropus*.

3.   Features Relating to Calvaria and Face

120.   There is great variability in size and form of calvaria and face, and in the development of many special structures.   However, the general *Sinanthropus* character remains unchanged. The same degree of variability occurs in modern man, in all known types of fossil man and anthropoids alike.   Yet there is one exception.   The difference between small and large skulls and certain of their peculiarities, as regards size and robustness, seems to be greater in *Sinanthropus* than in modern man if a definite population rather than mankind as a whole is considered.

It can be assumed with a great degree of probability that small specimens represent females and large ones males.   Sexual differences in size of similar extent are characteristic of gorilla and orang-utang but are much less pronounced in chimpanzee.   The same differences in size, and

apparently also in sex, occur in *Pithecanthropus.* In Neanderthalians they seem to exist but are not so marked as in *Sinanthropus* and *Pithecanthropus.*

121. In *Sinanthropus* the cranial suture appears to close at an earlier age than in modern man. Such early fusion is very characteristic of anthropoids. In *Pithecanthropus* the early fusion is even more pronounced than in *Sinanthropus.* Conditions among the Neanderthalians are not known, but there are indications (sequence of tooth eruption) that they, too, may age earlier than modern man.

The sequence in which the sutures close differs from that of modern man. In *Sinanthropus* the coronal suture closes first and then the sagittal suture follows while the reverse is true of man.

This list of 121 cranial characters contains only those described in the preceding chapters. Therefore, it does not touch on those of the mandible and dentition which have been dealt with in previous publications. Neither all the metrical nor non-metrical peculiarities have been included. Selection was made of those special features which seem to be present in all main phases of human evolution and are indispensably connected with the transformation of the skull as such. Furthermore, characters of accessory significance, so far as implied in other measurements, have also been omitted. For instance, of all the indices used in plotting the index-diagram of the vault only the vertex-height index has been recorded in the analysis-list, since this index can be considered as a representative indicator of the cranial height. Then too, all the characters disclosing the phylogenetic evolution of the skull will receive attention in one of the following chapters.

III. THE CHARACTER OF THE SINANTHROPUS SKULL

The position of *Sinanthropus* in the line of hominid types leading from unknown ancestral forms to modern man can be easily determined on the basis of the skull material at hand and its comparison with other hominids. There can be no doubt that *Sinanthropus*, although closely related to the different Neanderthal types, must be considered much more primitive than any representative of that group. On the other hand, comparison with *Pithecanthropus*, now on a much safer basis since the discovery of three more skulls, gives evidence that *Sinanthropus* comes much closer to this type than to any one of the Neanderthalians. Of the 121 characters of the *Sinanthropus* skull listed above 74 can be checked on *Pithecanthropus.* The remaining 47 refer to parts which are not preserved in the latter. In 57 out of these 74 characters *Sinanthropus* and *Pithecanthropus* agree with each other completely. Eight characters remain doubtful because the region concerned is damaged or obscure in the case of *Pithecanthropus.* Five characters are of accidental nature (metopic suture, os incae etc.) and, therefore, cannot be used for purposes of classification. Consequently there remain but four main characters in which *Sinanthropus* and *Pithecanthropus* differ (see the chapter in Part III dealing with *Pithecanthropus*).

The special character of *Sinanthropus* and his close relationship with *Pithecanthropus* was at once recognized by Davidson Black. He claimed (1931): "a type is represented differing profoundly from any of those represented by the Neanderthaloid, Rhodesian, modern hominid or anthropoid groups," and stressed the fact: "It early became apparent that the skull of *Sinanthropus* resembled that of *Pithecanthropus* much more closely than it did any of the Neanderthaloid, Rhodesian or modern types."

When Black came to these conclusions only two skulls were known (Skulls E and D or, according to my numbering, Skulls II and III). But the form they revealed was so character-

istically different from all the known hominid forms that almost all the students of Early Man unconditionally accepted Black's statements. The succeeding discoveries of additional material strengthened and confirmed Black's conception. I was myself so impressed by the general resemblance between *Sinanthropus* and *Pithecanthropus* that my first paper on *Sinanthropus* (Natur und Museum, vol. 60, 1930, pp. 546–551) bears the title: "Ein neuer *Pithecanthropus*-Fund in China." Elliot Smith (1931) and Sir Arthur Keith (1931) consented to Davidson Black's classification of *Sinanthropus* without any reservation. So did Weinert (1931) who considered *Sinanthropus* only as a "confirmation" of *Pithecanthropus*. Marcelle Boule (1937) puts *Pithecanthropus* and *Sinanthropus* together in one hominid group, inferior to the Neander-thalians, and calls this group "Prehominids." Le Gros Clark (1940) goes so far as to propose dropping the name *Sinanthropus* and replacing it by the name "*Pithecanthropus pekinensis.*"

In strange contrast to the unanimous chorus of agreement uttered by authors who possess at least some authority on problems of fossil man, stood and still stands, Hrdlička. In an appendix to his book "Skeletal Remains of Early Man" (1930), published before Black's mono-graph on Skull E came out, he characterized the skulls as "clearly Neanderthaloid" and con-tinues: "It appears to represent no distinct genus, species or *even a pronounced variety* (italics mine) and it is not like the lowest type of the Neanderthals but corresponds rather to the better developed specimen of that class, such as the Galilee Skull." It is true, Hrdlička made a reserva-tion in saying: "How far this still necessarily provisional view may be substantiated, remains to be seen." But in the review of Black's monograph on Skull E, Hrdlička, on the whole, repeats his previous statement (Amer. Jour. Phys. Anthr., vol. 16, 1931/32, p. 100): "The characteristics of the *Sinanthropus* remains approach this form most closely to that of the Neanderthals. It may be well to bear in mind in this connection the extraordinary variability of the Neanderthal man. . . . The extensive drawing upon of the *Pithecanthropus* is risky." In reviewing my paper on the *Sinanthropus* dentition, a proper place for Hrdlička to bring his early provisional opinion more in accordance with facts later discovered, Hrdlička confines his review (Amer. Jour. Phys. Anthr., vol. 24, 1938/39, p. 240) to the title and remarks: "The volume of text is marred by wide speculations which are not always sustainable." Unfortunately, the author did not take pains to specify the "speculations" and to tell which were "sustainable" and which were not. It can only be supposed that he considers the primitive character of *Sinanthropus* and his association with *Pithecanthropus* as speculative. In any event, it is evident that Hrdlička has not changed his mind in the more than nine years which have passed since he made his first statement on *Sinanthropus*.

Never was a statement more astray than Hrdlička's which brought *Sinanthropus* into the field of the Galilee skull. How little *Sinanthropus* has in common with this Palestine skull has been shown by McCown and Keith (1939). In their monograph on the Mount Carmel group, in which they include the Galilee skull, they expressly decline to compare it with *Sinanthropus* because of their "distant" relationship. I would not have dwelt upon Hrdlička's apparently unshakeable standpoint, had he not written the following sentence in his criticism of Davidson Black's paper (see above): "There is no need for and there is a positive danger in far-projected theories of origins and derivations; they may retard rather than advance critical studies and definite deductions." So far as I know the history of paleoanthropology, there was never any danger from far-reaching theories which have always been put into their right place by the facts, but rather from prejudice and obstinate retention of out-moded ideas. Even after the discovery of the Spy and Krapina skulls the famous German anthropologist, Rudolf Virchow, insisted on

considering the Neanderthal Skull of Duesseldorf, not as a form of early man but as the skull of a Russian soldier who died during the Napoleonic wars. For thirty years Virchow barred the sound development of palaeoanthropology in Germany and in those countries following her guidance. Another abhorrent example is the attitude which E. Dubois has adopted toward von Koenigswald's new discoveries of *Pithecanthropus* skulls. Dubois attributed them to *Homo soloensis* or even *wadjakensis* rather than acknowledge their *Pithecanthropus* character. In this case the danger of veiling truth is small, for everyone familiar with the skulls will reject Dubois' protest.

As mentioned above, Hrdlička has advanced the opinion that *Sinanthropus* does not represent "a distinct genus, species or even a pronounced variety." In point of fact, to decide the place *Sinanthropus* occupies in the line of human evolution and his relationship to the various hominid forms hitherto known, it is absolutely necessary to compare each of these types with *Sinanthropus*. The preceding chapters have done this to some extent but there are other facts which could not be taken fully into account there. In such a study each type must be considered separately, for I regard *Sinanthropus*, together with *Pithecanthropus* as the form which, because of general characters as well as special features, occupies the lowest place of all the hominid forms known so far. As such it may serve as a prototype which provides a clue to the better understanding of the characteristics of all other types. It may be superfluous, in this connection, to stress the fact that I am speaking only of morphological characters: neither space nor time can play any rôle in the zoological classification of human types. It is certainly not permissible to consider a form "primitive" only because it is geologically more ancient than some other; nor may it be considered more advanced because it is geologically more recent.

SINANTHROPUS COMPARED WITH THE OTHER HOMINID FORMS AND THE ANTHROPOIDS

A. *Sinanthropus* and Alleged Primitive Hominids

I. *"Eoanthropus"*

In the preface to Friederichs' paper on the calvaria and mandible of Piltdown (1932), I came to the following conclusions on the Piltdown finds: (1) The mandible shows all the characteristics of an anthropoid mandible and may belong to a form similar to the orang-utang of today; (2) The bones of the calvaria show all the characteristics of modern man with no special feature recalling the conditions of a primitive type; (3) Mandible and calvaria belong neither to the same individual nor to the same type; (4) The designation *"Eoanthropus"* is based on an erroneous interpretation of the finds and must, therefore, be eliminated. In following years I had the opportunity not only to study the originals but to compare them with such acknowledged primitive hominids as *Sinanthropus* and *Pithecanthropus*. In my paper on the mandible of *Sinanthropus* (1936b) I wrote: "The Piltdown mandible does not approach *Sinanthropus* any closer than any orang-utang mandible does." I further stated that it is impossible to say that the Piltdown jaw is more primitive than that of *Sinanthropus* because the former is not within the line of evolution from which *Sinanthropus* has derived: The Piltdown mandible is that of an anthropoid; the *Sinanthropus* mandible that of a hominid. In my paper on the *Sinanthropus* dentition (1937b) in which a thorough comparison was made between the isolated Piltdown teeth and those still *in situ*, I arrived at the following conclusion: The teeth of the Piltdown remains are of three different origins. The two molars embedded within the mandible are typical anthropoid teeth revealing peculiarities such as are found even in the orang-utang of today. These teeth, therefore, correspond entirely in their morphological character to the mandible in which they are embedded. The isolated, left molar is a molar of modern man. The additional, isolated tooth which was found and called "canine" neither belongs to the mandible, as claimed, nor is it the lower canine of an anthropoid. Its real nature remains to be determined.

In the meantime nothing has been published in favor of the *"Eoanthropus"* theory which invalidates my statements, so far as mandible and teeth are concerned. On the contrary, in 1939 the fragment of a mandible with three teeth *in situ* was discovered in the Sangiran district of Central Java from which the new *Pithecanthropus* finds have been recovered. This mandible excells both in size and robustness any mandible of fossil anthropoid or hominid which has so far been found. I only announced this spectacular discovery a little time ago (1942) and shall publish more details very soon elsewhere. R. von Koenigswald at once recognized the hominid character of this extraordinary mandible and has proposed for it the name *Meganthropus palaeojavanicus* because it differs so notably from the *Pithecanthropus* mandible. There can indeed be no doubt that this giant mandible reveals striking hominid characters in the bone as well as in the teeth. But this mandible is as different from the mandible of Piltdown as any orang-utang mandible is from that of *Pithecanthropus* or modern man. I shall return to this question later.

As to the calvaria of Piltdown, Sir Arthur Keith has recently (1938/39) made the attempt to correct his earlier reconstruction of this cranium, prompted by the discovery of the Swans-

combe Skull which he considers, to a certain extent, similar to the Piltdown calvaria. Before entering into a discussion of Keith's new statements on the Piltdown bones, the results of the comparison I made between the frontal, parietal, occipital and temporal fragments of Piltdown and the corresponding bones of *Sinanthropus* may be considered. Regarding the frontal bone, Piltdown fragments I and II possess none of the special features which are characteristic of primitive hominids. They have neither supraorbital nor glabellar tori. There is not a specially strongly developed zygomatic process. A supraorbital notch is present but not a supraorbital process. There is a distinct lacrimal groove. The cerebral relief is not pronounced and does not extend toward the roof of the cranial cavity. The parietal bone shows the regular size and form of recent man. There is not the slightest indication of either a torus angularis, a sagittal crest or a parasagittal depression. On the inside of the bone the Sylvian crest is completely absent. The relief of the sphenoid angle does not differ from the usual appearance in modern man. The pattern of distribution of the middle meningeal vessels represent that of an advanced type of modern man (cf. also Weidenreich, 1938b). The fragments I and II of the occipital bone are without any trace of an occipital torus; the superior nuchal line has exactly the same character as in any modern human skull. The same is true of the configuration of the nuchal plane. The cerebellar fossae are large and deep; undoubtedly much larger than in *Sinanthropus* or *Pithecanthropus*. Since the cerebral fossae are not complete, a comparison of the two is impossible. The transverse sulcus is wide and well developed on either side. The condition of the protuberantia occipitalis interna is not quite clear but the bend of the right transverse sulcus occupies the same level as the inion. The squama of the temporal bone is broken off to a great extent, but as the squamous suture at the parietal bone is preserved it is possible to form a judgment on the form of the squama; it was certainly not triangular and the parietal margin was well curved. The sulcus processus zygomatici is deep and narrow. There is a typical modern-human articular tubercle and the entoglenoid process of the mandibular fossa was apparently formed by the processus spinosus of the sphenoid. The tympanic plate is in a vertical position; there is no tegmen pori acustici; the porus is vertically oval and there is a marked postglenoidal process and a typical spina supra-meatum. The pyramid is straight throughout its entire length; there is a typical modern-human styloid process and a typical vagina. The pyramid is high and short and the margo superior edged; the relief of the facies superior is well pronounced. The cerebral fossa is wide and high. The mastoid region is well developed; the mammillary process projects directly downwards and the outer surface does not bend in a median direction. There are a heavy, well developed supramastoid crest and an supramastoid sulcus. There was apparently a deep and narrow mastoid notch.

All fragments have extraordinary thickness as a common character. But this thickness shows three very significant differences when compared with *Sinanthropus:* (1) As all the fragments show, the thickness is due to a great increase in the spongy substance of the diploë, while the external and internal tables are of normal breadth. (2) The thickness involves only the walls of the braincase but neither the tympanic plate nor the petrous portion; (3) The massiveness is not combined with a system of reinforcement such as is characteristic of all really primitive hominids. The nasal bones are relatively small or little pinched and exhibit no specific feature.

Influenced by the Swanscombe find, Sir Arthur Keith submitted the Piltdown bones to a reexamination for primitive features. The most striking anthropoid character he has discovered was absence of the "Sylvian falx" rising from the cerebral surface of the sphenoid angle of the parietal bone. As I have repeatedly shown in the preceding pages, the absence of this formation

is not a primitive character but an advanced one. This new discovery proves, therefore, not the simian nature of the parietal bone but, on the contrary, its modern-human character.

It follows from the statements of this summary report that neither the bones of the first Piltdown skull nor those of the second calvaria show any of those features which are really specific of primitive hominids. There are two or three which are found in the Piltdown fragments but these are such features as occasionally occur also in modern skulls.

The general form of the braincase can only be judged on the basis of a reconstruction of the fragments. The history of the Piltdown skull shows that, so far, not less than six such attempts have been made and that each of the reconstructions differs from the other. The reconstructions may be listed as: Woodward; Woodward-Barlow; Elliot Smith; Keith I; Friederichs; Keith II. Some of these attempts clearly show a tendency toward making the vault as low as possible in order to adapt it to the general conception of a primitive skull. Sir Arthur Keith directly admits that his second attempt, recently (1938/39) made, was influenced by the Swanscombe Skull then newly discovered and showing a relatively low vault. The author was indeed successful in so far as his first reconstructed skull has a length-auricular-height index of 60.4, but the second one only an index of 56.7 (Woodward-Barlow 50.4). The figures for the different hominid groups as given in Table XXVII are as follows: *Sinanthropus*, 50.9; *Pithecanthropus*, 52.2; *Homo soloensis* 53.0; Neanderthalians, 56.7 and modern man 61.7. The length-total height index of Keith's reconstruction II amounts to 69.2. For the five hominid groups the figures are, in the same sequence: 59.4; 59.6; 60.2; 63.2; 72.9. From these figures it follows that if even the lower length-height index of Sir Arthur Keith's Piltdown reconstructions is accepted, the measurement still falls within the range of modern man—or at best within that of Neanderthalians—but never within the range of really primitive hominids. In Figure 254 some of the Piltdown reconstructions are represented as index-diagrams using the nasion-opisthion line as base. The diagram shows that Sir Arthur Keith's second reconstruction together with that of Woodward-Barlow falls between the average of the Neanderthals and modern man. Only Friedrichs' reconstruction falls beyond the average of modern man. As the minimum and maximum values cover a wide field of variations (the length-height index above n-o ranges from 84.3–98.4), Friedrichs' reconstruction reaches the upper and Woodward's and Keith's are just below the lower average, provided the latter reconstructions are correct—a point I contest. Figure 255 shows Keith's second reconstruction again as index-diagram standing just in the middle between Rhodesian skull and the average of modern man.

Be this as it may, the problem in the Piltdown case remains the question whether or not it is at all possible that a mandible and tusk with anthropoid characters and a calvaria with modern-human ones could have belonged to the same individual. In other words, can the "missing link" be represented by "loose" juxtaposition of pithecoid and modern-human skeleton elements? I say "loose" because no part of the face is preserved which links the mandible fragment and the frontal or temporal bone. Sir Arthur Keith (1938/39) affirms: "On account of the mandible I have nothing to add or withdraw to what I have already given except to say that all the studies I have made of the cranium since 1915 . . . have convinced me more firmly than ever that skull and mandible are in harmony and formed parts of the same head." The studies I have made in the meantime in this matter lead me to the opposite opinion. All the discoveries of recent years show one fact very impressively, namely that characteristic primitive features are retained much longer in the calvaria than in the mandible. Sir Arthur Keith should know this best; Skhūl V of the Mount Carmel population which he considers as some kind of inter-

mediate between Neanderthal and modern man has already developed a modern human chin with a tuber symphyseos and a mental spine, although the frontal bone carries heavy and far-projecting supraorbital and glabellar tori. Almost the same combination is characteristic of *Sinanthropus;* the formation of the chin is not as advanced in this case as in Skhūl V but the tuber is already indicated and the mental spine well developed in spite of the fact that the bones of the braincase have preserved their most primitive characters. The newly discovered giant mandible of Java I mentioned above has no chin but already shows the human pattern in the configuration of the entire front region including a rudiment of the mental spine. But the converse combination has never been found: that is, a mandible with ape-like front region and a modern-human braincase in which even the supraorbitals have disappeared. I have shown in another paper on the brain and its rôle in the phylogenetic transformation of the skull (1941b) that not only in the entire primate order but also in other mammalia, there is a strict correlation between size and form of the braincase and size and form of the jaws; the larger the former the more reduced the latter and conversely (cf. Figs. 202, 203, 206, 221). This rule holds good for all anthropoids and hominids, so far as they are known today. *"Eoanthropus"* alone would defy this law.

In addition, the Piltdown canine which Sir Arthur Keith continues to regard as belonging to the mandible differs sharply from the canine of primitive man. As *Sinanthropus* gives evidence, the lower canine of a primitive hominid is incisor-like (Fig. 274, B; and Weidenreich, 1937b; 1939a) and the robustness of its crown does not exceed that of the premolars (cf. Weidenreich 1937b; Diagram 4, p. 76). Lower canines which resemble in form and robustness those of anthropoids cannot occur in hominids.

Lastly I wish to call attention to a fact which, so far as I know, has been overlooked constantly in any discussion of the Piltdown problem. It is claimed that all the bones, the mandible as well as the calvaria, belong to the same geological layer and, therefore, to the same period which has been determined as Interglacial Günz-Mindel. How then can it be that the calvarial bones, which already had at this early time the complete characters of modern man, remained completely stationary while the mandible and teeth underwent a number of important transformations until they reached the modern-human pattern? I know very well that there are nuances in interpretation among the proponents of *"Eoanthropus."* Sir Arthur Smith Woodward considers him as the common ancestor of Neanderthalians and *Homo sapiens* whereas Sir Arthur Keith (1925) believes that *"Eoanthropus,"* Neanderthalians and modern man all came from the same ancestor with simian mandible and teeth and "a brain equal in size to that of modern man." "In the course of evolution" the latter author assumes "the first named (*Eoanthropus*) retained the ancestral form of the mandible and teeth; the last (Neanderthal and modern man) preserved the ancestral simian features of the skull." Therefore, *"Eoanthropus"* must be regarded as "a representative of an extinct form of man." This sounds to me completely confused. For we are not dealing with the brain but only with the morphological character of the bones of the vault which do not reveal any difference from those of modern man. The human ancestor, therefore, must have possessed an already completely developed human vault—regardless of his direct or indirect relationship to modern man—together with simian mandible and simian teeth. In Neanderthal man the mandible and teeth are undoubtedly more human than in *"Eoanthropus"* but the vault is more simian than in the latter. All this in spite of the fact that, according to Sir Arthur Keith (1939), Neanderthal man preceded modern man immediately and got mixed with him—at least in so far as the Mount Carmel population is concerned.

In reality there is no escape from confusing complications if one had once committed himself to impossible constructions. I am only wondering why, if a human vault, a simian mandible and an anonymous "canine" were combined into a new form, the other animal bones and teeth found in the same spot were not added to the "*Eoanthropus*" combination; I do not believe in those miracles whether offered by anti-Darwinian or Darwinians. The sooner the chimaera "*Eoanthropus*" is erased from the list of human fossils, the better for science.

II. SWANSCOMBE SKULL

If the left parietal and the occipital bones which are all that is left of the so-called Swanscombe skull be submitted to the same analysis as the Piltdown skull as regards likeness or unlikeness to *Sinanthropus* and *Pithecanthropus*, we come to the conclusion that this calvaria, too, reveals no primitive hominid character.

The parietal bone is relatively small but considerably larger than the average of the *Sinanthropus* and *Pithecanthropus* parietal bones. Its curvature in transverse direction is the same, or even a little more pronounced, than in *Sinanthropus* but this might occur also in modern man as Figure 195 (hyperbrachycephalic human skull) shows. There is no sagittal crest and no parasagittal depression. There is, furthermore, not the slightest indication of an angular torus. The squamous suture is not straight but slightly curved, but there is a distinct parietal incisure. The cerebral surface shows no vestige of a Sylvian crest and the distribution-pattern of the middle meningeal vessels is that typical of modern man (cf. Weidenreich, 1938b).

The occipital planum of the occipital squama is much larger than the nuchal planum. The triangle formed by the occipital squama is relatively high and narrow. There is no occipital torus but every evidence of an already advanced stage of disintegration. But, as I have pointed out earlier (1940b), there are some peculiarities which bring the Swanscombe occipital bone closer to the Steinheim skull and the Neanderthalians. As to the cerebral surface, the cerebellar fossae are small in proportion to the cerebral fossae, the internal protuberance being located very close to the opisthion and distant from the inion level. The sulci are of normal, modern human size. The curvature of the entire occipital bone is much wider than that of *Sinanthropus* and *Pithecanthropus*.

Regarding the form of the skull, so far as it may be judged from the two cranial bones—all that is preserved—, the skull was relatively low but its maximum breadth certainly lay above the base and near the tuberosity of the parietal bone (cf. Fig. A, Pl. V in the Report, 1938). The skull was very massive but its thickness does not reach that of the *Sinanthropus* or *Pithecanthropus* bones.

From this report it is evident that the Swanscombe skull cannot be considered as a primitive hominid skull. It has all the appearance of a modern human skull. However, the occipital bone exhibits some features which, although not of a primitive nature in themselves, are found in the Ehringsdorf group of Neanderthalians (see later). It is, therefore, not entirely impossible that the missing frontal bone may have had supraorbitals like those of the Steinheim skull or the Skhūl population of Mount Carmel. But this also remains doubtful.

III. *Africanthropus njarasensis*

According to Weinert (1939/40) *Africanthropus* should be attributed to the *Pithecanthropus-Sinanthropus* group of early man. The author claims that the curves of the craniogram fall completely within the range of those of *Sinanthropus* and differ distinctly from those of the

Neanderthalians. To appraise the real value of this statement it is necessary to remember that the craniograms to which Weinert refers are those of his highly questionable reconstruction. The original calvaria of *Africanthropus* was broken into almost 200 small pieces most of them without any connection whatever. A glance at Weinert's illustrations of the unretouched fragments and his attempts to join them together (Weinert, Pl. 34, Figs. 1–5) reveals both large and small gaps between individual pieces so that reliable reconstruction is impossible.

But even if the reconstruction should be adopted as correct, it at once becomes evident that *Africanthropus* is quite another form from *Sinanthropus* or *Pithecanthropus*. In Figure 256 the contours of the two Sinanthropus skulls (A and B), the Rhodesian skull (C) and the reconstructed *Africanthropus* skull (D) have been put side by side in occipital view, using the Frankfort Horizontal and the interporial line for horizontal and vertical orientation, respectively. The occipital view of *Africanthropus* is a copy of Weinert's figures (pp. 265, 266). The form of the *Sinanthropus* skull as indicated by its contour line has its maximum breadth just above the porion level and then bends sharply in median direction around the very pronounced parietal tuberosity. In the Rhodesian skull there are no such bends: the breadth remains the same up to the much less developed tuberosity. The contour line of *Africanthropus* is thus more like that of the Rhodesian skull than that of *Sinanthropus*.

In addition, if the index-diagram above n-o is constructed on the basis of Weinert's midsagittal craniogram (Weinert's figures 10 and 11), it comes close to those of the Neanderthal group. Moreover, none of the *Africanthropus* fragments show any individual features such as those peculiar to *Sinanthropus*. Unfortunately, only a small portion of the left supraorbital region and a larger part of the occipital bone are preserved. As for the temporal bone, Weinert gives two illustrations of the left bone, one from below (Pl. 34, Fig. 5), and one from above (Pl. 35, Fig. 1). But no details are recognizable nor is there any precise description in the text. So far as the illustrations show, the supraorbitals were not separated from the frontal squama proper by a furrow as is the case in *Sinanthropus*, but present only the thickened end of an otherwise continuous frontal slope. They appear even less independent features than in certain skulls of modern Australian aborigines like the one depicted in Figure 254. There is an occipital torus in *Africanthropus*, but as Weinert's Figures 4 and 6 (Weinert's Pl. 35) show the torus has already disintegrated, a condition which is indicative of a later evolutionary stage.

As for the teeth, A. Remane's description (pages 302, 303 in Weinert's paper) provides no hint that they are of a primitive character. The teeth are so worn that the pattern of the occlusal surface remains obscure. Remane himself refrains from any verdict on the nature of the dentition. His remark that wrinkles may not have existed on the upper molars indicates that they differed greatly from those of *Sinanthropus* and were more like those of modern man.

Taking all these facts into account, *Africanthropus* cannot be considered as the African form of *Pithecanthropus* or *Sinanthropus*. I do not deny that there are some peculiarities pointing to primitive features. But this primitiveness cannot have gone beyond that of European Neanderthalians and certainly not beyond that of Rhodesian man. *Africanthropus* may be placed tentatively, together with the Florisbad skull (see later), in the neighborhood of the latter; that is all that can be conceded in view of the defective material at hand.

B. *Sinanthropus* AND *Pithecanthropus*

As mentioned in the last paragraphs of the preceding chapter, *Sinanthropus* almost immediately upon the discovery of the first skull, was regarded by the overwhelming majority of palaeo-

anthropologists as a hominid form strikingly similar to *Pithecanthropus*. At the time of the *Sinanthropus* discovery only the defective skullcap of Trinil was known, so that comparison was limited to a relatively small portion of the calvaria. Meantime the situation has changed. The *Sinanthropus* specimens have been considerably increased and newer and more complete specimens of *Pithecanthropus* have come to light. If teeth, mandible and limb-bones are disregarded and only calvaria counted, there are now three *Pithecanthropus* specimens available in addition to Dubois' type of Trinil.

The discovery of *Pithecanthropus* Skull II was announced by von Koenigswald (1938) and the skull briefly described and compared with *Sinanthropus* by von Koenigswald and myself (von Koenigswald and Weidenreich, 1939). *Pithecanthropus* Skull III was discovered in 1938 and the discovery announced by von Koenigswald and myself (von Koenigswald and Weidenreich, 1938). The discovery of *Pithecanthropus* Skull IV was shortly mentioned in a joint paper (von Koenigswald and Weidenreich, 1939). The reconstruction of the badly crushed skull was executed by myself and published under the title: Man or Ape? (Weidenreich, 1940a). In addition I referred to this skull in my paper on the occipital torus (1940b) which also included some drawings of the specimen. Quite recently von Koenigswald (1942) published photographs and drawings of all three *Pithecanthropus* skulls in a paper in which he discussed the relationship between *Pithecanthropus* and the South African man-apes on the basis of the dentition. Von Koenigswald also prepared a detailed description of Skulls II and III, but this paper, owing to the political situation, has been delayed.

When Dr. von Koenigswald was a guest of the Cenozoic Research Laboratory in Peking in 1939, studying the recently found *Pithecanthropus* material and comparing it with *Sinanthropus*, we made an arrangement between us regarding publication. By this agreement, each had the right to use his knowledge of both subjects and photographs, drawings and measurements in order to facilitate, as much as possible, the study of both hominids. In pursuance of this agreement I have continued to make comparisons between *Pithecanthropus* and *Sinanthropus* in the preceding pages. What remains is the discussion of the special character of *Pithecanthropus* and his position in the line of human evolution.

Before doing this, it seems well to explain briefly why the human fossils of Java, designated as *Pithecanthropus* Skulls II, III and IV, are considered to represent the same type as the Trinil skull-cap. This is especially necessary, since Dubois strangely objected to such a classification (cf. Dubois 1938), especially in the case of Skull II. The main arguments upon which Dubois depends are the greater thickness of the bones and the massiveness of the supraorbitals in the latter skull. Apart from this, Dubois asserts that von Koenigswald made the skull lower when reconstructing than it actually was, in order to adapt it to the Trinil cap. All these objections are without any foundation. The outer surface of the Trinil skull is eroded, to a great extent, and the lower surface of the supraorbitals is broken off (Figs. 259, 260), so that this specimen cannot serve as a gauge for the thickness of the other *Pithecanthropus* skull or for its special structures. In addition, the difference in thickness between Skull I and Skull II is negligible and meaningless considering the great variability in bone thickness shown when even individuals of the same type are compared. This is shown by the *Sinanthropus* skulls (cf. Table XXXV). As for Dubois' last argument that the skull was reconstructed incorrectly either intentionally or by accident, that may be dismissed by mere reference to Figures 257 and 258. Both figures are skiagrams of Skull II indicating the course of the coronal-sagittal (Fig. 257) and the sagittal-lambdoid sutures (Fig. 258) and were taken long after there construction was made. In addition

to the course of the sutures, the photographs show the breakage lines which cross the skull cap and the sutures in various directions. The fact that the sutures run without any deviation from the normal proves incontestably that the reconstruction of the broken calvaria is correct. Any intentional or unintentional divergence from the original position of the fragments would have been revealed in the skiagrams by a disturbance in the course of the sutures.

But there are additional and more positive facts of morphological character which give evidence of the similarity between Skull II and Skull I (Trinil skull-cap). In Figures 259 and 260 the two skulls are depicted side by side; Skull II (B) reduced to the length of Skull I (A). Figure 259 A shows the skulls from the left side; Figure 259 B from the right side and Figure 260 shows them from above. The white line in Skull II marks the line where Skull I is broken off. The figures reveal—even to anyone not familiar with skulls—such a complete conformity that it appears superfluous to dwell on the matter further. Even those features which were apparently peculiar to Skull I recur in Skull II: for example, the mid-sagittal contour of the slope of the frontal squama and its way of continuing into the supraorbitals; the bregma prominence; the rounding of the obelion; the slight inward curvature beyond it; the configuration of the occipital torus etc. The skulls differ from each other in two features only. Skull II is smaller than Skull I, a matter already discussed in a preceding chapter, and the post-otic part of Skull II seems to be more rounded than that of Skull I. The latter difference, however, may be due chiefly to the extensive erosion of Skull I and to a post-mortem depression of its right side (cf. Fig. 260).

Pithecanthropus Skull III belongs to a juvenile individual whereas Skulls I and II represent adults of apparently advanced years, as is indicated by the almost complete fusion of the sutures. Despite the defectiveness of Skull III (cf. Fig. 247), the fact that it belongs to *Pithecanthropus* cannot be questioned. Figure 261 shows the fragment as it was recovered when the matrix still adhered to the cerebral surface. As the vault is broken off along the coronal suture the anterior aspect of the fragment looks like a frontal section through the skull. It reveals the typical pattern of *Pithecanthropus* and *Sinanthropus* skulls; namely, the development of a sagittal crest; parasagittal depression; the sharp bend at the center of the parietal tuberosity and the outward slope of the parietal bone below (cf. Fig. 261 with Figs. 19 and 237 D). In addition the parietal bone is very thick, measuring 10 mm. on either side of the sagittal suture. As the occipital torus of Skull III is just in the state of developing (Fig. 247) and the sagittal and transverse arcs of the right parietal bone are 5 to 6 per cent smaller than those of Skull II, the individual cannot have been much older than eight years of age. For we know that the enlargement of the modern-human-calvaria amounts to only about 10 per cent and practically to nil in anthropoids after deciduous dentition has been completed. Therefore, provided the juvenile Skull III was of the same small type as Skull II and considering the probability that in early human types the growth of the brain and braincase stopped earlier than in modern man (cf. Weidenreich, 1940b), *Pithecanthropus* Skull III is that of a child possibly of the same age as that represented by the *Sinanthropus* Mandible B I (cf. Weidenreich, 1936b, Pl. II and Pl. XI–XV, Fig. 3).

The attribution of the Skull IV to *Pithecanthropus* was based on the fact that the maxilla and the calvaria were recovered from the same site (Sangiran district) and the same layer (Trinil beds) where Skulls II and III and Mandible B (cf. von Koenigswald and Weidenreich, 1939) were found. The teeth of the maxilla (Fig. 248) correspond in size as well as in their general and special form to those of Mandible B. The calvaria has many features in common with Skull I and II such as lowness, greatest breadth close to the base, heavy and continuous occipital torus,

massiveness of the bones etc.   On the other hand, there are a number of peculiarities in which Skull IV differs from II and III.   These differences particularly concern the superstructures which are enormously exaggerated.   This refers particularly to the occipital torus, the muscular relief of the nuchal plane and the sagittal and supramastoid crests (cf. Figs. 229 and 230).   The exaggeration, however, is not limited to these structures but involves other features also.   The pyramid, as already described, reaches large dimensions.   The same is true of the mastoid process, and the thickness of all the bones which exceed considerably that of Skulls I and II. Other special features of the skull have to be added: the transformation of the sagittal crest into a chain of partially isolated knobs; the enormous dimensions of the maxilla; the presence of a distinct diastema between canine and lateral incisor and a perfectly smooth palate (Fig. 248). These differences may be explained as sexually conditioned; if the smaller Skulls I and II are considered as females, Skull IV may pass as a male.   Such a view has been held in this and in previous papers.   But I must confess that neither diastema, smoothness of the palate nor the strange appearance of the sagittal crest fit too well into this explanation.   Moreover, the difference in massiveness between the supposed females and males is much greater than in corresponding cases of *Sinanthropus*.

I would have liked to pass over these disharmonies with the consoling thought that they are peculiarities of *Pithecanthropus* for which there is no explanation completely satisfactory in the present state of material at hand.   The discovery of the giant from the Trinil beds of Sangiran, as mentioned above, may, however, shed new light on this problem.   I will discuss this phase extensively elsewhere and, therefore, now confine myself to but few comments.   The giant mandible certainly does not belong to a type like Skull IV, for mandible and teeth are much too large.   Yet their presence proves that we have to reckon not with *one* but with several types of early hominids in the Far East.   These lived in Java as well as on the mainland of Asia and exceeded in size as well as massiveness of their cranial bones all that has been so far known.   What is their relationship to *Pithecanthropus*, if this type is represented only by Skulls I, II and III, is hard to say.   But it may turn out that there were smaller, intermediate types connecting the giants with the classical *Pithecanthropus* type.   It should also be borne in mind that the mandible fragment from Kendeng Brubus, described by Dubois (1924) in his first publication on *Pithecanthropus*, is much smaller than Mandible B, so that considerable differences in size, exhibited by the new specimens, has already been exemplified not only for the calvaria but also for facial bones.

In the last paragraph of the preceding chapter it has been shown that *Sinanthropus* shares almost all his essential characters with *Pithecanthropus*, so far as they are preserved in the latter or are not merely individual variations.   There are only four exceptions.   Of these the size of the braincase is the most important.   Even admitted that the value of the cranial capacity of *Sinanthropus* can drop to about 850 cc., the average still amounts to 1075 cc. whereas the cranial capacity of the three *Pithecanthropus* skulls available reveal an average of not more than 870 cc., or 200 cc. less than the average of *Sinanthropus*.   This difference of approximately 20 per cent in brain size is all the more significant as the increase of cranial capacity in human evolution seems to proceed very slowly.   The smallness of the *Pithecanthropus* braincase does not appear in a lesser height of the vault but as a general decrease combined with an absolute as well as a relative thickness of bone.

The differences in the forms of the vault concern the frontal, obelion and occipital regions. The frontal squama of *Pithecanthropus* is fairly flat and does not show the bump-like protuber-

ance characteristic of all the *Sinanthropus* skulls; although less well developed in Skulls X and XII, it is shown in Skulls III and XI (cf. Figs. 259 with Figs. 49, 50; 61, 62; 73 and 74). Conversely, the obelion region which is somewhat vaulted in *Pithecanthropus* is depressed in *Sinanthropus* (cf. the same figures). The absence of the bump in *Pithecanthropus* seems to cause the frontal squama to continue into the frontal torus without any distinct demarcation whereas in *Sinanthropus* they are separated by a broad furrow. In their horizontal outline the *Pithecanthropus* skull conforms to the "Sphenoides" and the *Sinanthropus* skull to the "Ellipsoides" of G. Sergi's classification; in other words, the occiput of the *Pithecanthropus* skull is broad and rounded while that of *Sinanthropus* is narrow and elongated (cf. Figs. 260 with Figs. 53, 65, 77).

· Regarding more specialized features, the frontal sinus is much more expanded in *Pithecanthropus* than in *Sinanthropus* (see above). There seems to be no tendency in *Pithecanthropus* to develop "Inca bones" or exostoses (torus mandibularis, ear and maxillary exostoses) as they occur in *Sinanthropus*. On the other hand, it is strange that the same kind of sharply localized obelionic depression which Black has described in *Sinanthropus* Skull III (1931) is also found in *Pithecanthropus* Skull III (Fig. 247, do).

This comparison would not be complete unless mandible and teeth were included. This, however, is not the place to make a detailed description of *Pithecanthropus* Mandible B, the teeth in this jaw, and the maxilla of Skull IV since the description of all this material is reserved for Dr. von Koenigswald by our agreement. I am obliged, therefore, to confine myself to some remarks.

Regarding the mandible, the greater robustness of the frontal part of Mandible B is the essential difference between that and the *Sinanthropus* mandibles. The "index of robustness" measured on the level of the interstice between medial and lateral incisor (corresponding to the line of breakage) amounts to 52.5 in *Pithecanthropus*. That of the male *Sinanthropus* Mandible G I to 38.9; of the male *Sinanthropus* Mandible K I to 36.6, and the female *Sinanthropus* Mandible H I to 46.4. When the measurements of height and thickness, however, are taken at the level of the mental foramen (according to Topinard) the index amounts to 44.5 in *Pithecanthropus* against an average of 55.5 for the four adult *Sinanthropus* mandibles (A II; G I; H I; K I). In other words, the *Pithecanthropus* mandible is considerably thicker than the *Sinanthropus* mandible, so far as the frontal part is concerned; the lateral portion is thinner when the measurement is taken in the conventional place. On the other hand, the *Pithecanthropus* mandible agrees with that of *Sinanthropus* in: (1) the absence of an alveolar plane, (2) the development of a distinct elevation at the spot of the mental spine, (3) the multiplicity of the mental foramen which presents at least three small openings arranged around the elevated center as is specific of *Sinanthropus*.

The characteristics of the permanent dentition of *Pithecanthropus* has been defined quite recently by von Koenigswald (1942) as follows: "(1) the first upper premolar has three roots: (2) the second upper molar is larger than the first; (3) the second lower premolar (when compared with the first molar) is very large, surpassing in its length, absolutely as well as relatively, the same tooth in recent man; (4) there is a decided increase in length from the first to the third lower molars, the latter being the largest tooth of the whole series." Von Koenigswald's summary refers (as the author stresses) to those characteristics by which the *Pithecanthropus* dentition differs from that of other hominids. In this paper we are only interested in the differences between *Pithecanthropus* and *Sinanthropus*. Unfortunately, however, von Koenigswald has omitted to tell whether or not he included *Sinanthropus* in the "other hominids." Therefore, claimed differences have to be taken with a grain of salt, as far as *Sinanthropus* is concerned.

Regarding the first difference recorded in von Koenigswald's statement, the three roots of the upper premolar can only refer to *Pithecanthropus* Skull IV. Unfortunately, the author does not say how he found out that this tooth has three roots. Possibly skiagrams were made but no pictures are given, and it is important to know whether the three roots are free or fused. For, in one case, *Sinanthropus* has two, separated roots, the bigger of which shows signs of an additional partition. In two other cases the roots are fused but the original, three-rooted character of the tooth still remains recognizable (cf. Weidenreich, 1937b; Pl. 9, Figs. 64–68, 73c and d). On the other hand, three entirely separated roots can even occur in modern man (M. de Terra, 1905) while fused roots are found also among the anthropoids (Remane, 1921). Therefore, the mere statement that the upper premolar of *Pithecanthropus* has three roots is not precise enough, particularly when it is followed by the conclusion that "in this respect *Pithecanthropus* is nearer to the man-apes and anthropoids than it is to man" and *Sinanthropus* is ignored.

According to Dr. von Koenigswald, the second upper molar of *Pithecanthropus* is larger than the first one. This is a distinct difference from all other hominids, *Sinanthropus* included as Fig. 262 shows. But this figure is drawn on the basis of the measurements of *all Sinanthropus* molars available, teeth *in situ* as well as isolated, and teeth not belonging to the same jaw. If however, only those cases are taken into account in which first and second upper molars belonging to the same maxilla and the same side are measured, the second molar is larger than the first in *Sinanthropus* also. The robustness of the first molar (length multiplied by breadth) in three of those cases totals 117, 125 and 131 and that for the second 132, 130, 142 (see Table 16 in Weidenreich, 1937b; p. 64). It must be admitted that in the only case of *Pithecanthropus* Skull IV (right side) the difference in size is much greater; the corresponding figures amount to 166 and 207. But, in any case, this is only a quantitative and not a qualitative difference due to the exceptional character of Skull IV.

The third difference noted by von Koenigswald refers to the proportional length of the second lower premolar and the first lower molar. In *Pithecanthropus* Mandible B the premolar length is 72.6 (9.3 : 12.8) per cent of the molar length—one case only; in *Sinanthropus* it is 69.8 (an average of five and seven cases, respectively) and not 64.3 as recorded by von Koenigswald. If we accept a single case as typical, *Pithecanthropus* has a slightly larger second premolar than *Sinanthropus* and so, in this respect, comes closer to the anthropoids in which the ratio is about 80.0. As Figure 263 shows, however, the difference in robustness of the premolar in proportion to that of the first molar is nil when *Pithecanthropus* is compared with *Sinanthropus*. In both forms the robustness of the premolar amounts to 60 per cent of that of the first molar. This is about the same difference as in chimpanzee (62.3). In modern man the premolar is much smaller, the ratio dropping to 52.0. The female gorilla comes very close to *Pithecanthropus* and *Sinanthropus* with a ratio of 57.0. Only the orang-utang shows very small differences. In the female the ratio is 78.0 and in the male 92.0; in other words the premolar is very large in relation to the first molar.

The fourth difference noted by von Koenigswald concerns the size of the third lower molar. This molar is not the "largest" of the molars, as von Koenigswald claims, but only the longest. The lengths of the three *Pithecanthropus* molars (one case: Mandible B) arranged from the first to the third are as follows: 12,5; 13,0; 14,5. In *Sinanthropus* the average figures of seven, six and four cases, respectively, are as follows: 12,6; 12,6; 11,2. This is indeed a difference, for it reveals that *Pithecanthropus* does not tend, like *Sinanthropus* and modern man, to reduce the length of the third molar. On the other hand, the feature should not be overestimated, as the

Pithecanthropus molar exceeds the two preceding in length only, lagging behind in breadth; for the breadth measurements reveal M_1 13.1; M_2 13.4; M_3 12.5. The robustness of the third *Pithecanthropus* molar is, therefore, as Figure 263 shows, greater than that of M_1 but not greater than that of M_2. In *Sinanthropus* and modern man the molar is much smaller. But in all the anthropoids except gorilla the third molar is smaller than the second one. In gorilla the third molar is by far the largest of all three teeth (cf. Fig. 263). This is, however, not the case in *Pithecanthropus*.

Of the four main differences between the *Pithecanthropus* and the *Sinanthropus* dentition listed by von Koenigswald, only the fourth is a real one, provided it is not merely an individual variation. As for the size of the teeth, only the upper molars of *Pithecanthropus* Skull IV are larger than the biggest of *Sinanthropus* molars (cf. Fig. 262). Of the lower molars of *Pithecanthropus* Mandible B, only the second and third are larger than the largest *Sinanthropus* molars (cf. Fig. 263). This does not mean, however, that *Pithecanthropus* has generally larger teeth than *Sinanthropus*. The Mandible B and the maxilla of Skull IV have particularly large dimensions and are undoubtedly much larger than would be expected for female *Pithecanthropus* individuals such as are represented by Skulls I and II. The average size of the *Pithecanthropus* teeth, therefore, hardly exceeded the average of *Sinanthropus*.

More important than the recorded differences are those features in which *Sinanthropus* appears as the more primitive type. Both *Pithecanthropus* and *Sinanthropus* agree in the development of a cingulum but this is more pronounced in *Sinanthropus* than it is in *Pithecanthropus*. The second lower premolar of *Sinanthropus* is also strikingly anthropoid in the form and pattern of the crown (cf. Weidenreich, 1937b) while the *Pithecanthropus* premolar exhibits the human pattern and form in greater degree. The first and second lower molar of *Sinanthropus* are characterized by the following peculiarities: (1) the length is greater than the breadth; (2) the trigonid is broader than the taloid; (3) there is a very distinct *Dryopithecus* pattern; (4) the metaconid is the largest and longest cusp. None of these features are developed in *Pithecanthropus*; the breadth is smaller than the length or of the same dimension; the greatest breadth falls on the middle of the tooth; the *Dryopithecus* pattern is less pronounced and tends toward the "plus" pattern; the metaconid is of about the same size as the protoconid.

Are the differences between *Sinanthropus* and *Pithecanthropus* great enough to justify their complete separation and, if so, which one should be considered as the more primitive form? Von Koenigswald, impressed by the small size of Skull II and that of its mastoid process, declared first (1938) *Pithecanthropus* to be the more primitive form. I, considering these differences indecisive and influenced by the undoubtedly primitive character of the *Sinanthropus* dentition, inclined to the opposite opinion (1937d; 1938a). Now, after the recovery of additional *Pithecanthropus* material, this debate has become more meaningless. As shown above, both forms have so many features in common and their differences are so far from the characters of the Neanderthalians and related hominids, that both must be regarded as representatives of the same stage of human evolution. The question, therefore, becomes: Are these two forms sufficiently alike to justify the dropping of the name *Sinanthropus* in favor of the earlier name *Pithecanthropus*, as was recently recommended by Le Gros Clark (1940a, b), and Zuckerman (1940)? Since this recommendation is based on scruples about using different names for types regarded as generically identical, I shall revert to it in a later paragraph. However, there is certainly no perfect identity between *Sinanthropus* and *Pithecanthropus*. Although some features are represented in one *Pithecanthropus* specimen only, other features occur in more cases.

The latter may, therefore, be regarded as typical and not as individual variations. This holds good for the differences in size and form of the braincase, for the form of forehead, frontal torus and occiput. These differences, however, certainly go no deeper than those between two races of modern mankind. A bumped forehead, for instance, is common among negroes but not found in whites; a deep infraglabellar notch is characteristic of Australian aborigines and Melanesians but absent in Mongols. The average of the cranial capacity amounts to 1310 cc. for male Australians and to 1154 cc. for female ones, but reaches 1563 cc. for male Eskimo and 1458 cc. for females. In other words, the Australian braincase holds about 200 per cent less than that of the Eskimo; exactly the same difference exists between the *Sinanthropus* and *Pithecanthropus* braincases. I do not wish to minimize the differences between these two hominid forms but, considered from the morphological viewpoint, they are of the same kind and magnitude as modern racial differences.

This conception does not exclude, of course, the fact that some features must be accounted more primitive in one race than in another. The diastema of the maxilla and the smoothness of the palate in *Pithecanthropus* Skull IV, together with the low cranial capacity of all three *Pithecanthropus* skulls, undoubtedly indicate a more primitive phase than the corresponding features of *Sinanthropus* do. But this primitive condition is compensated on the *Sinanthropus* side by other primitive traits which are lacking in *Pithecanthropus*—a condition particularly true of the *Sinanthropus* dentition. The races of modern man show différences of the same character. Australian aborigines and whites are considered as different races of the same human, evolutionary type despite the fact that the former has retained, from the standpoint of the anthropologist, much more primitive features than the latter.

In such a discussion of differences and likenesses between *Pithecanthropus* and *Sinanthropus*, the problem posed by the femur cannot be completely disregarded. I can be brief on this point since I have only recently discussed the matter in my paper on the limb bones of *Sinanthropus* (1941a) to which the reader is referred. I doubt more than ever that the Trinil femur—and still more the four Leyden femora subsequently recognized by Dubois and attributed to the same hominid type as the Trinil skull-cap—really belong to *Pithecanthropus* as represented by the skulls of which we are speaking. If they do, the number of characters which separate *Sinanthropus* from *Pithecanthropus* would be increased but in a direction opposite to that indicated by the braincase. For the *Pithecanthropus* femora undoubtedly resemble those of modern man much more than do the femora of *Sinanthropus*.

It is useless, as things stand at this moment, to argue whether *Pithecanthropus* or *Sinanthropus* is the more primitive form within their evolutionary group. But it seems much more promising to trace the individual features—so far as possible—to their origin and leave the final verdict to the future. This is all the more justified since the entire *Pithecanthropus* problem has assumed a different aspect because of the recent discoveries in Java and South China. As indicated earlier, I entertain doubts whether *Pithecanthropus* Skull IV can be attributed to the same group as the Trinil skull and von Koenigswald's Skulls II and III. The coarse massiveness of the bones, the strange development of the sagittal crest and the large size of the maxilla contrast too sharply with the relatively small and delicate Skull II, even if we admit that sexual differences may have been more pronounced in *Pithecanthropus* than in *Sinanthropus* or other hominids. Skull IV irresistibly reminds us of the recently found giant human mandible, although the latter is still larger and more massive than the maxilla of Skull IV. The combination of a diastema and a smooth palate—features more ape-like than any observed before in hominids

—together with teeth of a human character have their equivalent in that giant mandible of Java. Its bulkiness which exceeds all that is known of any primitive mandible is united with a hominid-like cross-section through the chin region, the first indication of a mental spine, and enormous but undoubtedly human teeth.   In addition, the recent discovery of a slightly worn "Giganto-pithecus" lower molar, made by von Koenigswald in South China, makes the placing of "Gigan-topithecus" (von Koenigswald 1935) in the hominid group almost a certainty.   Those teeth far surpass in size all known primate teeth and even the teeth of the Javanese giant hominid. Thus we have to reckon with the existence of giant hominids in South Eastern Asia showing considerable difference in size amongst themselves.   Should *Pithecanthropus* Skull IV belong to this giant group, or to one intermediate between it and the smaller *Pithecanthropus* Skulls I, II and III, not only its massiveness but also the more anthropoid character of its maxilla would find plausible explanation.   In such case, Skull IV would be placed nearer to the anthropoids than to *Sinanthropus* and the *Pithecanthropus* Skulls I, II and III.

I did not include "*Homo modjokertensis*" in the *Pithecanthropus* list.   My reason for this is that there does not exist a similarly young *Sinanthropus* skull or skull fragment with which the baby skull of Modjokerto could be compared.   The only one which corresponds approximately is *Sinanthropus* Skull VII represented by a piece of the occipital bone (Figs. 41–45), although this skull was apparently older than the Modjokerto skull.   Regarding the classification of the baby's skull of Modjokerto, I have revised the earlier opinion I advanced.   I then felt that it did not belong to *Pithecanthropus*.   A thorough examination of the original specimen has led me to the conclusion that the skull must be attributed to the *Pithecanthropus* type.   I hope to be able to publish a study on the Modjokerto skull in the near future.

C.   *Sinanthropus, Pithecanthropus,* AND *Homo Soloensis*

It is a great pity that the skulls which were discovered, in 1932, by Oppenoorth (1932a, b) on the bank of the Solo River in Central Java near Ngandong and designated as *Homo soloensis* are still awaiting detailed description.   This delay is all the more regrettable because the skulls are not merely a new addition to our little knowledge of Neanderthal man, as the preliminary publications suggest, but a discovery of the utmost importance in regard to the locality and character of the finds themselves.   Oppenoorth in his second paper (1937)—unfortunately not less preliminary in form than his first—concedes that it may be his own fault that these skulls have been so badly underestimated.   Their significance may have been shadowed by this lack of complete detail.   The author is quite right.   Thanks to the kindness of Professor W. D. Mijsberg who has been intrusted with the study of the skulls, I had the opportunity of examining the originals briefly in Batavia.   And thanks to Ir. W. C. B. Koolhoven, Director of the Geological Survey of the Netherlands Indies, who presented a complete set of casts to the Cenozoic Research Laboratory, I was able to subject these skulls to a more thorough investigation.   I am greatly indebted to both gentlemen for this help.   For it would have been almost impossible to have completed my work on the *Sinanthropus* skull without having access to an indispensable source of knowledge of primitive hominids as *Homo soloensis* presents.   Everyone who is engaged in these studies will feel the dilemma of my situation when faced with the fact that, thus far, no detailed description of the Ngandong skulls has been published.   There were a great number of data known to me which threw new light on the problem of Java man as well as on *Sinanthropus*. To complicate the situation, any further communication with Java was impossible on account of the political situation.

I decided, therefore, to use the Ngandong material only to such an extent as was inevitable in understanding its special character. A rectification of the data given here will be necessary anyway, because most of the measurements and craniograms have been made from casts and should, therefore, be verified on the originals. Unfortunately, the originals are not in the best condition. They were apparently badly damaged when discovered and their restoration leaves much to be desired, especially so far as Skulls IX and X are concerned.

Oppenoorth's first paper did indeed give the impression that the Ngandong skulls were of a Neanderthal type. The only essential difference, according to Oppenoorth, was "the characteristic formation of the occiput" meaning the sharp bend of the nuchal plane and a very pronounced occipital torus. This, however, is not at all specific, for it is found even more pronounced in the Rhodesian Skull. Since further details were not available and Oppenoorth's measurements and craniograms yielded no more information, I came first to the conclusion that *Homo soloensis* represents a Neanderthal form. Two peculiarities however were clearly recognizable in the lateral view of Skull I depicted by Oppenoorth (1932b, Fig. 3). These were the relatively flat forehead and its almost direct continuation into the frontal torus and, in contrast with this, the well-vaulted occiput with its abrupt falling-off toward the occipital torus. Both features are well developed in all Ngandong skulls and must, therefore, be regarded as typical (cf. Fig. 264 B). They made me distinguish "*Homo soloensis*" as "*Homo primigenius asiaticus*" from the European Neanderthalians, which I had called "*Homo primigenius europaeus*" in a previous publication (1928c), and from the Rhodesian skull, called "*Homo primigenius africanus*."

I learned by examination of the originals and the casts that I was wrong, not in attributing *Homo soloensis* to a special race (see the following paragraphs), but in failing to recognize that this "*soloensis*" type possesses a great number of essential features which place it in a more primitive evolutionary group than the one represented by the Neanderthalians. When I made the attempt in recent years (1939a; 1940c) to classify the Neanderthalians according to their morphological characters and grade of primitiveness, I came to the conclusion that three main groups have to be distinguished. I tentatively called these the Rhodesian Group, Spy Group and Ehringsdorf Group. *Homo soloensis* and *Homo rhodesiensis* were considered to be the only representatives of the Rhodesian Group.

This study, however, shows that arranging *Homo soloensis* and Rhodesian man in one group does not take sufficient account of the more primitive state of *Homo soloensis*. In the analysis of the general form of the skull and the special features given above I listed 121 individual characters to serve as guides when the types have to be judged. As facial bones, mandibles and teeth are completely missing in the case of *Homo soloensis*, a verdict can only be based on 69 morphological characters of the calvaria recorded in the analysis above. Five of them have to be excluded because they represent purely individual or racial variations which do not offer information as to the position of the type. Six are doubtful on account of the indistinctness of the originals. In the remaining 58 characters there is almost complete conformity with *Sinanthropus* or *Pithecanthropus* except for two characters.

The characters in which *Homo soloensis* differs from *Sinanthropus* and *Pithecanthropus* are the size of the calvaria and the cranial capacity. The maximum length of *Homo soloensis* ranges from 193 mm. to 219 mm. against 188 to 199 mm. in *Sinanthropus*, and 176.5 mm. in *Pithecanthropus* II and 183 mm. in *Pithecanthropus* I (cf. Tables XIX, XXII and XXVI). The differences in breadths are much smaller: the average maximum breadth of *Homo soloensis* is 146 mm.; that of *Sinanthropus* 141 mm. and that of *Pithecanthropus* II 135 mm. The differences in the

auricular height are also greater. The average auricular height is 107.4 in *Homo soloensis*, 98.4 mm. in *Sinanthropus*, and 89 mm. in *Pithecanthropus* II. In spite of these differences in the three dimensions of the calvaria, the capacity is not correspondingly greater. This becomes evident when the inner skull length of *Homo soloensis* is compared with that of *Sinanthropus*. Although, probably, the measurements of the former may be somewhat corrected when taken on the originals, the disparity between outer and inner measurements will remain great. The average inner skull length is 161 mm. in *Homo soloensis*, and 166 mm. in *Sinanthropus* as against 148 mm. in *Pithecanthropus* II. In other words, the extraordinary length of the *soloensis* skulls is chiefly due to the extreme massiveness of the skulls and the great development of the super-structures. The average thickness of the anterior and posterior cranial walls on the level of the maximum length measurement (glabella and opisthocranion-inion) amounts to 48 mm. in *Homo soloensis*, but only to 28 mm. in *Sinanthropus*, and 22 mm. in *Pithecanthropus* (in modern man the difference is about the same as in *Pithecanthropus*). Therefore, the cranial capacity of *Homo soloensis* is surprisingly small in view of the large size of the calvaria, since it ranges from only 1035 cc. to 1255 cc. with an average of 1100 cc. This is considerably less than Oppenoorth's estimate (1937) for the three skulls: I, V and VI. But even this estimate falls short by about 100 cc., and, even if the average were a little greater (about 1200 cc.), it would still be markedly below the average of the Neanderthalians and very close to that of *Sinanthropus*.

Angles and indices (Tables XXIII and XXVII) reveal the same fact. The index-diagram (Fig. 222) shows that the height and proportions of the *Homo soloensis* calvaria (computed with the nasion-opisthion line as base) coincide almost completely with that of *Sinanthropus*. Only the opisthocranion-inion region diverges, due apparently to the greater prominence of the occipital torus in the Ngandong skulls. The same diagram demonstrates that *Homo soloensis*, together with *Sinanthropus*, is a little higher than *Pithecanthropus*. But it has to be borne in mind that this diagram, so far as *Pithecanthropus* is concerned, has been calculated only on the data of Skull II, the smallest skull of all the types in question, because it alone yields reliable figures. The index-diagram of Figure 255, on the other hand, shows how widely *Homo soloensis* differs from all the Neanderthalians, the Rhodesian Skull included. If one clings to the classification of *Homo soloensis* as a Neanderthalian, he certainly has to be placed right at the bottom of this group.

But there are other characteristics which render such an attribution difficult. The conformity between the Ngandong and *Sinanthropus* skulls consists not only in the general form and the proportions of the calvaria but in the special features also. As Oppenoorth (1937) has already stated, the greatest breadth of the Ngandong skulls is at the base although not pronouncedly so in all cases (cf. Figs. 197 and 198). With the important difference that the torus of the Ngandong skulls already shows signs of disintegration, the occipital torus recalls that of *Sinanthropus* Skull III and *Pithecanthropus* Skull IV (cf. Weidenreich, 1940; Pl. IV, Figs. 15 and 16, with Figs. 73, 74, 76 and 99—*Sinanthropus* Skull III—and Figs. 229 and 230—*Pithecanthropus* Skull IV—in this paper). The peculiarities of the temporal bone are of great interest. The form of the squama, the root of the zygomatic process, the formation of the articular tubercle and the mandibular fossa, the details of the tympanic plate and petrous and mastoid portions are practically the same as in *Sinanthropus* but differ from the corresponding features of the Neanderthalians, with the Rhodesian skull in this case on the Neanderthalian side. Some minor details are not quite clear on account of the indistinctness of the originals: so far as I was able to observe, a vaginal process seems to have existed in *Homo soloensis* whether there was a styloid

process or not. If so, how long and thick the rudiment was; remains to be discovered. The superior orbital fissure is a short, oval opening as in *Sinanthropus*. The lacrimal groove is absent in some cases but present in others. The supraorbitals are also not uniformly shaped; in some cases they are strangely compressed but whether this compression is a natural or an artificial one, I was unable to decide.

Although there is extraordinary conformity between the Ngandong Skulls and *Sinanthropus*, this is still greater when the Ngandong skulls are compared with the *Pithecanthropus* skulls for they possess the peculiarities in which *Pithecanthropus* differs from *Sinanthropus*. As listed above these peculiarities are: (1) Flat forehead in *Pithecanthropus* while the forehead of *Sinanthropus* is bumped. (2) Frontal torus in almost continuous connection with the forehead in *Pithecanthropus* but a separating groove in *Sinanthropus*. (3) Vast frontal sinuses with extension into the orbital roof in *Pithecanthropus;* small sinuses limited to the interorbital region in *Sinanthropus*. (4) Well-vaulted obelion region in *Pithecanthropus;* depression in *Sinanthropus*. To demonstrate some of these conformities I have depicted in Figure 264 Ngandong Skull V (B) in lateral view together with *Pithecanthropus* Skull II (A); in Figure 259 *Pithecanthropus* Skull I (A) is illustrated in the same aspect. A comparison of these figures reveals that the conformity of the contour line of the Ngandong Skull V and *Pithecanthropus* Skulls II and I is almost a perfect one except for the occipital torus in the Ngandong skull. However, this feature is much less pronounced in the other Ngandong skulls. The extension of the frontal sinus is, of course, not visible, but in discussing the pneumatization of *Sinanthropus* I have already called attention to the differences in this regard. In this feature also, the Ngandong skull shows complete conformity with the *Pithecanthropus* skull.

Considering all these facts there can be no doubt that the Ngandong skulls belong in the group of the "Prehominids," *Pithecanthropus* and *Sinanthropus*, but approach the former rather than the latter. On the other hand, there are definite indications pointing to a more advanced stage of the Ngandong skulls. This refers not so much to the larger size of the skull as to its capacity. Other features are combined with it; for instance, the tendency of the maximum breadth to shift upward toward the parietal tuberosity; the absence of the Sylvian crest and the expansion of the middle cerebral fossa; the disintegration of the occipital torus and, probably, also that of the frontal torus. All these changes must be considered as typical steps on the way to higher evolutionary stages. In other words, the Ngandong skulls are intermediate between the *Pithecanthropus* and *Sinanthropus* stage, on the one hand, and Neanderthal types, on the other.

It is not a pure accident that the Ngandong skulls resemble *Pithecanthropus* more than they do *Sinanthropus* or, generally speaking, the Java race of primitive hominids more than their North Chinese race. The morphological affinity, supported by the fact that the Ngandong population lived in exactly the same area as the *Pithecanthropus* population, but in a more recent geological period (see later), suggests that Ngandong man represents the next evolutionary step in the line leading from *Pithecanthropus* to modern man. The size and massiveness of the Ngandong skulls are more easily understood when one realizes that there is close relationship not only with the relatively small *Pithecanthropus* Skulls I and II but also with the big Skull IV and probably with the giant form whose presence in Central Java has been established.

D. *Sinanthropus, Pithecanthropus* AND THE NEANDERTHALIANS

In using the name "Neanderthalians" for the various forms of the hominid groups which have to be ranged between *Sinanthropus* and *Pithecanthropus*, on the one hand, and modern man

or "*Homo sapiens*" proper, on the other, I follow an old practice. It was first shaken by the discovery of the Rhodesian Man who stands at the base of this row and was shaken again by the discovery of the Mount Carmel population wich stands at its top. "Neanderthal Man," as originally represented by the skull cap of Düsseldorf and, as such, acknowledged as a well-defined type of fossil man, could maintain his isolated position only so long as no other stages were known. As the gaps filled, this isolation became lost and the difficulty arose and increased as to the name under which the newly discovered types could be pigeon-holed.

In 1927, Morant could still state that the "Mousterian Skull," represented by the skulls of La Chapelle, La Quina, Spy I, Spy II, Neanderthal, Gibraltar, Krapina, and Le Moustier, are "remarkably homogeneous" and furthermore that there is a "distinct hiatus which may be taken to indicate a specific difference" between Mousterian Man and all modern racial types. A year later (1928), Morant added the Rhodesian Skull as a new type to the list of the "Mousterian Man," called now "Neanderthaloid type." He defined the relationship between the Rhodesian and the Neanderthaloid type as follows: "It appears from a comparison of individual measurements that the Neanderthaloid type is rather less widely removed from modern man than the Rhodesian." Although he added that "a generalized coefficient based on 23 measurements suggests the reverse order." In any case, the discovery of the Mount Carmel population in the meantime removed the hiatus at the top of the row for McCown and Keith (1939) stated: "The Tabūn possesses many features which link it to the Neanderthal type of Europe while the extreme Skhūl type passes toward a Neanthropic form such as that found at Cro Magnon. Between these extremes are intermediate forms."

In the preceding paragraphs I was able to show that *Homo soloensis* is less "neanderthaloid" than was generally believed, so that now there exists an almost continuous evolutionary line leading from *Pithecanthropus* to modern man. It seems then, only a question of convention as to where the division between the differing types should be placed.

Neanderthal Man, Neanderthaloids or Neanderthalians passed for many years as a collective name for all hominids between those types which already possessed the characteristics of man—as, for example, Cro Magnon or Aurignac—and *Pithecanthropus*, considered as ranging close to the anthropoids. In 1928 (1928b), when more data concerning Rhodesian Man became known, I proposed to subdivide the whole Neanderthal group which I called "*Homo primigenius*" according to a plan suggested earlier by Wilser, into two types differing morphologically and regionally. These were named "*Homo primigenius europaeus*," represented by the European Neanderthalians, and "*Homo primigenius africanus*," represented by the Rhodesian Man. In 1932 (1932a), after the discovery of the Ngandong skulls I added "*Homo primigenius asiaticus*" to the list for the same reasons. The "homogeneity" of the Neanderthaloids of which Morant had spoken exists, in any case, only so long as a small number of less decisive characters are selected for the basis of classification as will be shown later. Here we must discuss whether the entire Neanderthal group when compared with modern man, on the one hand, and with *Sinanthropus* and *Pithecanthropus*, on the other, is homogeneous enough to pass as a unit which diverges from hominid types below and above this group.

In the preceding pages where the metrical and non-metrical characters of *Sinanthropus* have been compared with those of other hominids, reference has been made in each case to the Neanderthalians, their conformity or dissimilarity being noted. In all the tables, craniograms and diagrams the main representatives of the Neanderthal group are included. All these data give a uniform picture, free from any objection, in that they demonstrate that the general pattern as

well as the individual features of the Neanderthalians fit perfectly into the general plan of an evolutionary series, beginning with *Sinanthropus* and *Pithecanthropus* and ending with modern man. A glance at the index-diagrams of Figures 222 and 255 show better than any detailed description to what extent this statement is true. Regardless of the cranial capacity—be it 1610 cc. as in the case of La Chapelle-aux-Saints or 1270 cc. as in the case of the Skull of Tabūn I (cf. Table XXIV)—the average measurements (Fig. 222) keep between the averages of *Sinanthropus* and *Pithecanthropus*, on the one hand, and modern man, on the other. How far this also holds good for individual forms of the Neanderthal group, as, for example, the skulls of Rhodesia, Gibraltar, Steinheim and Skhūl V, is shown in Figure 255. Skhūl V comes very close to modern man while the Steinheim Skull approaches the average of the Ngandong skulls which, in their turn, are almost identical with that of *Sinanthropus* (cf. Fig. 222).

The wide range of variability between Skhūl V (or the Galilee Skull) and the Tabūn Skull I (or the Gibraltar Skull) makes it difficult to define, precisely, the morphological character of an individual skull within the Neanderthal group. The conventional measurements, as Figure 255 and Tables XXVI and XXVII show, are not sufficient for this purpose. Here are some examples: The length-height index, considered as one of the most indicative because it expresses the eventual lowness of the calvaria, ranges from 60.2 to 66.8 in the Neanderthal group and from 65.6 to 77.9 in modern man. The higher-vaulted individuals among the Neanderthalians overlap the group of modern man while the lower-vaulted among modern man overlap the Neanderthalians. The length-height index of the "Old Man" of Cro Magnon amounts to 65.4; that of the male Skull III of Předmost to 66.5, and that of the "Old Man" of the "Upper Cave" of Choukoutien (Weidenreich, 1939c) to 66.7. Still more pronounced is the overlapping in the length-auricular-height index; in *Sinanthropus* this index ranges from 50.0 to 63.0, in modern man from 54.8 to 71.5. The index for the three fossil forms of modern man mentioned (Cro Magnon, Předmost, Upper Cave of Choukoutien) are 59.8, 60.6, and 55.4, respectively. The same overlapping happens when the inclination-angles of the frontal squama above the glabello-opisthocranion line (no. 3, Table XXVII) are compared. This angle ranges from 38° to 51° in the Neanderthalians and from 42° to 57° in modern man. More than this, in all the ten angles and thirty-two indices used to distinguish the different hominid types from each other, Neanderthalians and modern man largely overlap except for one index, that of length-opisthion-height index. This index ranges from 50.9 to 69.8 in the Neanderthalians and from 70.7 to 81.7 in modern man. There is, therefore, a hiatus, although a small one, between the two groups. It may be only accidental that there is no overlapping in this feature; nevertheless, it is of some significance. For the length-opisthion-height index indicates the relative height of the vault above the opisthion with FH as base. The lower the skull in the opisthion region the lower the index. A vertical erected above the opisthion meets the roof of the vault between vertex and lambda, exactly that region of the calvaria which gains most by the expansion of the braincase in the course of evolution (cf. Weidenreich, 1936a; 1941b).

The fact, however, that there is no hiatus in the overwhelming majority of all the remaining metrical characteristics but instead a large overlapping proves: (1) We have an evolutionary continuous line leading from *Sinanthropus-Pithecanthropus* to modern man without awaiting additional discoveries; (2) The Neanderthal stage cannot be distinguished from lower or more advanced stages of this line by measurements alone; only the special combination of the measurable features and, above all, the non-metrical characters are decisive.

It would perhaps never have entered anybody's mind to attribute the Galilee fragment or, more recently, the Skhūl calvaria to the Neanderthaloid group were they not equipped with typical supraorbitals. This feature is one of the most characteristic peculiarities of all the fore-runners of modern man. On the other hand, we know no case in which typical supraorbitals persisted up to the stage of modern man. In Palæolithic Man of modern type mentioned above (Cro Magnon, Předmost, Upper Cave of Choukoutien—the man of Obercassel may be added) the supraorbital region bulges more than in modern man, but typical supraorbitals like those developed in the Neanderthal group are missing. When bulging superciliary arches occur in living races, as is the case of the Australian aborigines, these structures never exceed in size and strength those of the Palæolithic type of modern man. Strangely enough, the occipital torus is different. Despite the fact that this feature begins to disintegrate in a much earlier stage than the frontal tori—the Steinheim Skull has well developed frontal tori but its occipital torus has already disappeared—it may persist to an astonishing extent in modern man. In my paper on the occipital torus (1940b) I depicted the torus of a male Tasmanian (Pl. III, Fig. 11) the center of which is somewhat flatter than in the tori of *Sinanthropus* or *Pithecanthropus* but which, otherwise, does not show any great change. The frontal as well as the occipital tori belonging to the architectonic reinforcement-system of the hominid calvaria undergoes a gradual diminution as the brain and braincase expand.

The morphological character of the changes the two tori undergo while passing through the Neanderthal stage always follows the same principle, thereby proving that the Neanderthalians are really only a "phase" (Hrdlička, 1927) in the phylogenetic development of man. The course of the gradual transformation of the features appears confused since the single phases, theoretically expected, do not seem to succeed each other in unmistakable sequences. There are several reasons for those irregularities: (1) The range of individual variation. (2) The insufficiency of the fossil material. (3) A certain disharmony in the combination of seemingly fixed characters. The aforementioned persistence of the torus occipitalis in modern man and its almost complete disintegration in the Steinheim skull are instances of the last category. One encounters such disharmonies again and again whether dealing with teeth, cranial bones or bones of the extremities. One of the most striking examples which led to a quite erroneous concept of the character of human dentition is the Heidelberg Mandible, a combination of a very primitively looking, large, robust mandible and teeth close to those of modern man in size, form and arrangement. On the other hand, there is the Ehringsdorf Mandible with primitive teeth but symphyseal structures which recall the conditions of modern man to a much greater extent than the symphysis of the Heidelberg mandible does.

The frontal and occipital tori change during the Neanderthal phase through gradual disintegration and decrease of strength. The frontal torus of *Sinanthropus* consists, in reality, of three tori merged into one structure without any sign of demarcation, namely: the two supraorbitals and the glabellar torus between, all three being sharply separated from the frontal squama by the supratoral sulcus. The disintegration begins with the reduction of the middle section. In the Düsseldorf Skull the whole torus is already broken up; each of the supraorbitals has assumed an almost circular form keeping closely to the margin of the orbit; the glabellar portion has sunk between the two orbital half-rings which, in their turn, indicate additional subdivision into a medial and a lateral section. The latter brought about the development of a narrow depression which crosses the supraorbital torus obliquely from medial below to lateral above. At the same time the entire lateral half-ring portion decreases in thickness and tapers

toward the frontozygomatic suture, so that it gradually merges completely with the frontal squama. Complete disintegration has not been achieved in the Neanderthal phase but in the palæolithic form of modern man. Only the Rhodesian skull still exhibits the primary condition with very little alteration while the Gibraltar and Spy II skulls represent the most advanced stages.

The transformation of the occipital torus follows the same line as I have already described in a previous paper (1940b). None of the Neanderthal skulls, however, reveals the primary condition of the reinforcement-system of the post-otic region. The disintegration there is already in full swing. The mastoid portion has become independent; the angular torus has already disappeared and the original central portion around the inion shows all indications of a tripartite division such as leads later to the appearance of the supreme nuchal line and the external protuberance. No Neanderthal skull has reached this terminal stage. As already mentioned above, there seems to be no synchronism between the reduction of the frontal torus and the occipital torus. The latter usually disintegrates earlier than the former, although reverse conditions may occur. A well-defined frontal torus is rare in modern man whereas an occipital torus, at least so far as the middle portion is concerned, may still be found in primitive races.

In most of the non-metrical characters the Neanderthalians have already attained the stage of modern man. This holds particularly true for the numerous individual peculiarities of the three portions of the temporal bones. Very few of the primitive features which are so specific of *Sinanthropus* have been retained in the Neanderthal skulls. In the Krapina skull, for example, where the mastoid process was so poorly developed that Klaatsch (1902) called special attention to it, the tympanic plate and the pyramid do not display any difference from modern man despite the persistence of heavy and far-projecting supraorbitals in this type. The same is true of the Mount Carmel skulls. Even the Rhodesian skull exhibits a tympanic plate and pyramid which have the pattern of modern man. Such an insignificant formation as the spina supra meatum, which is absent in *Sinanthropus* as well as *Pithecanthropus*, has already assumed a typically modern form in Neanderthal skulls.

That the ranges in cranial capacity overlap in Neanderthal and modern man is one of the best known examples of metrical characters. If only those Neanderthal skulls are taken into account, which yield unobjectionable figures, the capacity ranges from 1220 cc. to 1610 cc. while the amplitude of the variations is rather smaller in modern man, ranging from 1125 cc. to 1540 cc. (Table XXVI)—when only the averages of the different racial groups and not individual measures are considered. Why this paradox is not incompatible with the evolutionary position of the Neanderthalians has been explained above. But from this fact it follows that, in judging individual cases, the cranial capacity is no more reliable for the recognition of a Neanderthal form than the length-height index is. The same is true of the dentition. The case of the Heidelberg Mandible has already been cited above. It is typical of other instances. Certainly, it is easier to recognize a Neanderthal mandible by the character of its chin than by the pattern of its teeth. Since the teeth of the Neanderthalians are so close to those of modern man, there is no more possibility of distinguishing primitive and more advanced types within the Neanderthal group by the character of their teeth only than it is within the group of modern man.

One of the most striking disharmonies came to light in the Mount Carmel population. It is not that a primitive type, like that represented by the Tabūn Skull I, lived, temporally and spatially, with advanced types as represented by the Skhūl skulls which is important. It is rather that the Skhūl Skull V, in spite of being equipped with heavy, far-projecting supraorbitals

possesses a mandible with a chin already well developed (cf. McCown and Keith, 1939). On the other hand, the Ehringsdorf skull, apparently belonging to the same type as the Galilee Skull (Weidenreich, 1928) and Skhūl Skull V, has a mandible without a chin. The occurrence of a chinless mandible in the female Tabūn Skull I side by side with the male Tabūn Skull the mandible of which has a chin (cf. McCown and Keith, 1939) conveys the same knowledge.

These incongruities are of the greatest importance when the phylogenetic position of the Neanderthalians and their relation to modern man are considered. So far, however, no one has taken notice of them, although the main problem has been discussed time and again, since the first Neanderthalian was discovered. Such an intermingling of primitive and advanced characters in the same specimen or the same type can only be interpreted as a sign of a still unbalanced and intermediate state of transformation.

The circumstance that each type which we rank with the Neanderthalians represents, in itself, an intermediate form does not mean that they are morphologically alike. As already mentioned, Morant regarded all as "homogeneous" (1927/28) and "equally related to all races of *Homo sapiens*." Yet this claim loses its value since Morant himself made the same statement with regard to the Rhodesian skull, though he found that the latter can be "clearly distinguished from the Neanderthaloid and modern types." This seems to me to be at variance with the geometrical theorem that two triangles are equal to each other if each one equals a third. In any case, the hominid forms between *Sinanthropus-Pithecanthropus* and modern man can be subdivided into at least four groups, the subdivisions being based upon the prevalence of more primitive or more advanced metrical and non-metrical characters.

(1) The first and, therefore, most primitive group which I called the "Rhodesian Group" (1939a; 1940a) is represented by the Rhodesian Skull only. *Homo soloensis* I first put into the same group. I now think it would be better to take him out and bring him in closer connection with the *Sinanthropus-Pithecanthropus* group, although, on the whole, he is a more advanced type. (2) The second group which I called the "Spy Group" embraces all the forms Morant has designated as Neanderthalians. The two Saccopastore skulls and the skull of Monte Circeo may also belong to this category. (3) The third group which I called the "Ehringsdorf Group" consists of the Ehringsdorf Skull, the Tabūn Skull, the Steinheim Skull, probably the Krapina skulls and the Kafzeh Skull of Judea. (4) The Skhūl skulls of Mount Carmel together with the Galilee skull can be attributed to the fourth group, intermediate between the Neanderthalians and modern man.

Taking all the facts recorded above into consideration, there is one general morphological line leading almost continuously from *Pithecanthropus-Sinanthropus* to modern man. This continuity makes it difficult to determine to which conventional group a special type may be attributed. The difficulty will increase as new forms come to light.

My survey of the Neanderthalians would not be complete unless the limb bones, particularly the femur, are mentioned. It is well known that the femora of Neanderthalians are very stout and heavy. This is based upon all femora so far preserved—Neanderthal, Spy, La Chapelle, Ferrassie, La Quina, Krapina and Ehringsdorf (Weidenreich, 1941a). All these femora belong to skulls attributed to Group II and Group III. No femur is available for Group I. Whether the femur attributed to the Rhodesian Man really belongs to this type is doubtful. In any case the alleged Rhodesian femur is like those of Group II. Neither has a femur of *Homo soloensis* been recorded. The femora of the Mount Carmel Population (McCown and Keith, 1939) differ somewhat from the usual picture: with the exception of the Tabūn woman whose

femora exhibit the most Neanderthaloid pattern, the femora are nearer to the modern human type. The *Sinanthropus* femora, on the other hand, deviate from the Neanderthalians as well as from modern man. They are strikingly platymeric, less stout in form and less robust in structure than the Neanderthalians but straighter and, in their middle sections, less constricted than those of modern man, but, on the whole, they are human and agreeing in some peculiarities with the femora of certain modern racial groups. The femora which E. Dubois ascribed to *Pithecanthropus* are of quite a different type. They are slender and long, possess a high pilaster, and cannot be distinguished in any way from those of modern man (cf. Weidenreich 1941a). Whether or not they really belong to *Pithecanthropus* must remain in abeyance. In any case, all the femur types of fossil hominids from *Sinanthropus* up to the intermediate group between the Neanderthalians and modern man are of human character. The differences they show are minimal, compared with their general appearance, but it is difficult to arrange them in such a classification as can be used for teeth or skulls. This indicates that the skeleton of the extremities acquired human character much earlier than the cranium. I shall return to this point later.

E.　*Sinanthropus, Pithecanthropus* AND "*Homo sapiens*"

It has been shown in the preceding paragraphs that a continuous line leads from the most primitive hominid forms, *Sinanthropus* and *Pithecanthropus*, up to modern man. The Neanderthalians, as a whole, have to be considered as, in the main, intermediate stages; they combine primitive and advanced characters, displaying gradual disintegration of original structures and adapting them to new requirements. According to the extent to which this process is realized, various special types, accidentally preserved from a long, unknown series of forms, have been singled out and determined by specific names. The form which has attained the latest stage in this long, evolutionary process has been named "*Homo sapiens*." "*Homo sapiens*" is, therefore, identical with what I have called in this paper "modern man" or, briefly "man"; identical with what Sir Arthur Keith likes to designate as "Neanthropic" man. "*Homo sapiens*" appears, however, uniform only when its general zoological organization is compared with those of the preceding stages or other primate groups. He can be divided into subgroups or races according to the presence or absence or diverging formation of specific features. For many years those races have been deemed very late acquisitions in the history of human ascent. It was not believed that they were achieved earlier than the stage of "*Homo sapiens*" himself. In a recent publication (1940) Howells says: "it seems likely that all races sprang from a type which was already *Homo sapiens*."

In his analysis of the characters of the Neanderthaloids and Rhodesian Man Morant (1928, 1937) arrived at the conclusion (already cited above) that those fossil forms are "equally related to all races of *Homo sapiens*." In other words, there are no earlier differentiations recognizable which could be analogized or directly connected with racial differentiations of today. But Morant did not indicate whether he regards the expressly acknowledged differences between Rhodesian and Neanderthal skulls as an equivalent of modern racial differences or merely as accidental, individual variations without classificatory significance.

I.　RACE, SPECIES AND GENUS

With this question we broach the vast problem of specific and generic relationship between the different types of fossil hominids and *Homo sapiens*. If the genealogical tree of man's an-

cestry depicted in the frontispiece of Sir Arthur Keith's "Antiquity of Man" (1925) is taken as a characteristic example of these attempts, one is surprised to find almost all the fossil hominids, known at this time, traced as side-branches of the human stem. Neither *Pithecanthropus*, the European Neanderthalians nor Rhodesian man lead to any form of modern man. In other words, the ancestors of *Homo sapiens*, and, therefore, also the ancestors of all the different races he represents are completely unknown—if we depend on such a pedigree. Only "Heidelberg," "Ehringsdorf" and "Neanderthal" are indicated as succeeding stages of the same side branch.

In the supplement to Keith's book, "New Discoveries" (1930), the original pattern of the tree was not changed. Only *Sinanthropus* has been added, and he, too, appears as a mere side-branch between *Pithecanthropus* and the Neanderthaloids. The main reason why Keith considered all these fossil forms as side-branches is given in the chapter of conclusions in his "Antiquity of Man." He admits that the discovery of Neanderthal man "confirmed us in our beliefs" that man "assumed a more and more primitive shape and structure" when traced into the remote past. Nevertheless, Keith sticks to the idea that Neanderthal man "cannot represent a stage in the evolution of modern man," because hominids of the modern type have been in existence long before the extinction of the Neanderthal type. In other words, Sir Arthur Keith bases his judgment on the relation of fossil hominids and modern man not on morphological facts but on geological considerations. Those considerations were apparently also decisive in his arrangement of Heidelberg, Ehringsdorf and Neanderthal men as succeeding stages of one of the side-branches, although the pattern and the development of the teeth of the Heidelberg mandible are much more advanced types than those of the geologically younger Ehringsdorf mandible. On the other hand, the Ehringsdorf skull comes very close to the Galilee Skull and appears less primitive than the classic Neanderthal skulls of the later geological period, as I have already emphasized in my paper on the Ehringsdorf Skull (1928). That geological considerations still play a decisive rôle in the argument is proved by Le Gros Clark's recent remarks (1940) referring to the same subject.

It has to be acknowledged that Sir Arthur Keith recently rather reversed his earlier opinion. In the joint paper of McCown and Keith (1939) the authors stress the facts that the Tabūn and Skhūl skulls of the Mount Carmel population show a mixture between Neanderthal and modern human characters, although their cultures are very nearly identical and they lived in the same localities and at approximately the same time. Furthermore, the authors acknowledge the existence of mid-Pleistocene "races" although these "races" have been all attributed to the "generic" group "*Palaeoanthropus.*" The different "specific" groups of the new genus *Palaeoanthropus* are the following:

1. *Palaeoanthropus heidelbergensis* (Heidelberg)
2. *P. ehringsdorfensis* (Ehringsdorf)
3. *P. neanderthalensis* (Düsseldorf and La Chapelle-aux-Saints)
4. *P. krapinensis* (Krapina)
5. *P. palestinensis* (Mount Carmel and Galilee)

Although McCown and Keith speak of "generic" and "specific" groups, it is evident that these designations are not used in the taxonomic sense, for the terms "race" and "species" are expressly applied by the authors as words of the same meaning. The authors consider the specimens of the Mount Carmel population as "members of the same species or race." In spite of

this declaration, it remains obscure whether the collective term "*Palaeoanthropus*" designates a real "genus" or only a "species." In any case, the confusion is now greater than it was before; the situation has not improved by the authors' claim that the Neanthropic type which "makes its appearance among the Skhūl people" is one of the "European-Caucasian or white" types. In the same breath they attribute the Skhūl people not only to another species but even to another genus.

When we are speaking of species and genus in reference to hominids, and particularly in reference to fossil hominids, we must first explain on which criteria such a distinction is based. The concept of species was always and is—perhaps more than ever—subjected to great divergence of opinions. There is no agreement among taxonomists and geneticists, not to speak of the minor differences between representatives of both groups. Palaeoanthropologists are in the same situation as palaeontologists. Palaeoanthropology deals only with teeth and bones—that is to say, with dead material never amenable to experiment. No inter-breeding will ever decide whether there is a relationship between "*Eoanthropus*" and an Englishman or between "*Eoanthropus*" and an anthropoid or of what kind such relationship may be. Even if—in the not too distant future—the geneticists should find a general formula applicable to human heredity, an answer to the *Eoanthropus* problem—or any other problem arising from palaeanthropological material—will never be given. Although it is of no practical use here to quote the latest definition of species based on purely genetical concept, I do it in order to demonstrate to certain anthropologists who want to reform anthropology on modern lines, that there is, in fact, no way to transfer genetic definitions to our material. Patterson (1942) circumscribes the species as follows: "A species is an actually or potentially interbreeding array of forms whose net mutation rate is greater than the actual or potential gene interchange with other arrays or forms."

There can, then, be no doubt that a classification of fossil hominid forms can be based—for the present and probably for ever—only on morphological characters. Simpson, speaking as a representative of palæontologists in a symposium on species definition, recently held at the New York Academy of Sciences, says (1943): "The palæontologist, by necessity, defines his species by morphology and not by transmission of heredity or breeding habits and potentialities." Furthermore, "A morphological species is a group of individuals that resemble each other in most of their visible characters and such that adjacent local populations within the group differ only in variable characters that intergrade marginally." "A taxonomic species is an inference as to the most probable characters and limits of the morphological species from which a given series of specimens has been drawn." Modern neozoological taxonomists reveal a growing tendency to get rid of morphological characters and prefer to rely on breeding habits and ecological factors. Mayr (1942) considers the morphological species concept as an "artificiality"; "a morphological species definition should be applied only as a temporary and provisional expedient as long as no additional information is available."

Therefore, the present situation is as follows: Morphological characters are the only ones available for palæoanthropologists and palæozoologists, although neither geneticists nor modern taxonomists acknowledge those characters as decisive for establishing species or races. In dealing with the classification of hominids, however, the situation is not as hopeless as it seems to be. What we really want to know is whether the morphological differences which are recognizable in different hominid specimens have to be accounted as merely individual variations within the same group of individuals or as indicating completely independent groups. We want, furthermore, to know whether the characters found in a given group of hominids are so different

from those found in groups of an earlier or a later time that they can be used as indicative of direct relationship in ascending or descending line. Whether we determine those groups as subspecies, species or genus is completely irrelevant for our purpose. In the case of man, we are in the convenient position of being able to refer to the generally acknowledged fact that at least the living mankind—in spite of the great variability of their characteristic features—represents only *one* species even in the sense of the most orthodox and most modern taxonomists. We can, moreover, refer to the "races" of the domesticated dog which have always been regarded as breeds of the same "species," although the grade of differences in size, form and special features of the skulls—Irish Wolfhound, on the one hand, King Charles spaniel, on the other, (Figs. 269 and 271; cf. also Weidenreich, 1941b)—match even the grades between gorilla and modern man (Figs. 270 and 272) leaving quite aside smaller differences as those between *Sinanthropus* and Neanderthaloids or Neanderthaloids and modern man.

To return to the starting point of this discussion, who can decide: (1) whether or not *Pithecanthropus, Sinanthropus* and the diverse forms of the so-called Neanderthaloids are independent side-branches of the human stem and have been extinct so completely as to have left no descendants who could have transformed themselves into modern mankind; (2) whether or not the morphological characters of the aforementioned groups are really so divergent in principle that they justify radical "specific" or "generic" separations? Darwin said in 1859: "In determining whether a form should be ranked as a species or a variety, the opinion of naturalists having sound judgment and wide experiences seems the only guide to follow." That nothing has changed in this regard since Darwin wrote this passage, more than eighty years ago, can be gathered from Dobzhansky's two latest (1942) utterances. They read as follows: "No other but purely morphological criteria are applicable when several forms succeeding each other in time are compared" and "Dividing an unbroken chain of forms into species or races is a matter of convenience only." Hooton (1931) appropriately criticizes a judgment depending only on the competence of the determining naturalist when he says: "In the matter of species or subdivision, such archaic and ape-like forms as Neanderthal man, Heidelberg man, *Sinanthropus* . . . have usually been assigned separate specific rank and have sometimes been elevated to the grade of genus. Everything seems to depend upon the systematists' idea as to the distinctness of the form he describes and the nearness or remoteness of relationship to other human types. Obviously this is a very subjective and arbitrary procedure."

The procedure in this matter was indeed always a "subjective and arbitrary" one. G. Schwalbe (1901) arrived at the following conclusions regarding the Neanderthal skull-cap of Düsseldorf: "the skull belongs to a form which differs from recent man specifically, perhaps even generically." But one seeks in vain for more precise an explanation of this categorical judgment. Schwalbe apparently considered the morphological differences between the Düsseldorf skull and modern human skull as great as those between species or genera of living animals. Marcellin Boule (1911/13) states that the man of La Chapelle-aux-Saints represents an archaic type which has disappeared. This disappearance means that he has become extinct without leaving behind any descendants. The author goes even so far as to indicate that he regards the La Chapelle Man as a "degenerated" type. In this case, too, no reason whatever based on really morphological facts is given. According to Boule the man of La Chapelle-aux-Saints cannot be the ancestor of *Homo sapiens* because *Homo sapiens*-forms (Cro Magnon, Grimaldi) lived in France simultaneously with the Neanderthalians. This is the same argument which Sir Arthur Keith (1925/30) advanced to set the Neanderthalians on a side-branch of his genealogical tree and to

consider Heidelberg Man, Ehringsdorf Man and Neanderthal Man as direct succeeding stages of this separated hominid line.

Let us set aside for a moment the geological-chronological aspect of the question and focus our attention on the morphological aspect alone. Throughout the whole history of palaeoanthropology one tendency is clearly manifest. The continuous misinterpretation of the position of the various fossil hominids is due to the fact that each student regarded the special object of his interest as a completely independent specimen. He examined it, feature by feature, but omitted to consider how and where it fitted into the general phylogenetic line. There is of course an excuse; in the beginning no such line was recognizable because the individual finds were too sporadic, too fragmentary or spatially too far apart. How finds consisting of a greater number of specimens may influence the judgment, the discovery of the Mount Carmel population has demonstrated. Now there is no longer the question of side-branches in Sir Arthur Keith's reports. In spite of the fact that the Tabūn and Skhūl populations represent two types of which the former is not distinguishable from the European Neanderthalians while the latter combines undoubtedly modern-human characteristics (high-vaulted calvaria) with very archaic ones (frontal torus), Keith regards all as representatives of a mixed population "in the throes of evolutionary change," and intermediate between *Homo sapiens* and *Homo Neanderthaliensis*— that same type which he once estimated as extinct and which Boule pushed aside as "degenerated."

The discoveries of recent years—*Sinanthropus*, the additional finds of *Pithecanthropus*, *Homo soloensis*—provide us with a wealth of new material leading farther down and so nearer to the original hominids than did any one of the earlier known forms. These new discoveries have offered the opportunity of tracing back each peculiarity of the Neanderthal skulls to its first appearance—so far as now known. Other new discoveries like the Mount Carmel and Steinheim skulls revealed what happened to those same peculiarities as they approached the modern human type. So we are able to understand the origin, the intermediate and definite aspects of each structure. Studies along such a line as I have followed in this paper make it possible to recognize the single phases of the evolution of the hominid skull in its general form as well as in its details, independent of the momentary state of a structure as it may appear in a given specimen. In so doing, one arrives at the conclusion that evolution, on the whole, follows a certain strictly-kept line without any indications of particular chance variations outside of the adopted pattern.

In preceding chapters I have shown, for instance, that: (1) the expansion of the braincase occurs with absolute regularity and with each bone involved in the process undergoing a characteristic transformation in its whole and in its minor structures (cf. Fig. 221). (2) The face, including the teeth, becomes reduced in strictly inverse proportion to the expansion of the braincase (cf. Figs. 203, 206, 221). (3) The decomposition of superstructures such as the frontal and occipital tori goes hand in hand with the expansion of the brain. I have furthermore shown that, although the general tendency is evident when the whole line is taken into account, the single phases of transformation are not always recognizable in the one single specimen, but there may exist great disharmonies which obscure the otherwise clear trend. Excellent examples of this condition are the Heidelberg Mandible in which dentition of modern-human pattern and arrangement is combined with a very archaic jaw-bone; or the Skhūl Skull V which possesses a high-vaulted braincase the capacity of which amounts to more than 1500 cc. combined with a well-developed frontal torus which, although it does already show signs of disintegration, could have been typical of any Neanderthal skull.

To explain the occurrence of these disharmonies we may again take the Heidelberg Mandible as an example. The jaw has to be attributed to the Mindel Glaciation, more precisely to the Interstadial Mindel I/Mindel II according to the most recent re-examination of all stratigraphic and faunistic evidences (Zeuner, 1940). This means that the mandible is much older than any Neanderthalians and about the same age as *Pithecanthropus* and *Sinanthropus*. Nevertheless, the teeth of the Heidelberg jaw are difficult to distinguish from those of modern man except for the greater strength and the length of the roots. This was the reason most authors believed that man, as a whole, had retained the same simplified tooth pattern from the early beginning of his history up to the present time. The discovery of *Sinanthropus* has proved the fallacy of this deduction. *Sinanthropus* has a dentition which so closely approaches the anthropoid as to appear, in some instances, rather anthropoid than human. *Pithecanthropus* shows the same general tendency. There is small doubt, therefore, that Heidelberg does not represent the original human dentition but already possesses an advanced one. If this is so, then there is no escaping the assumption that there existed a forerunner of Heidelberg Man who had the same primitive teeth as *Sinanthropus*. But this forerunner must have lived in Europe or elsewhere at a period more remote geologically than the Mindel Glacial. From this forerunner, Heidelberg Man may have inherited the massiveness and form of the mandible while the teeth underwent in the meantime their transformation into a more human pattern.

The Heidelberg Mandible is not the only case. The Steinheim skull belongs to the Riss Glaciation or, more precisely, perhaps to the Interglacial Riss I/Riss II, again according to Zeuner (1940). This means that the skull is much older than the classical Neanderthalians of the Düsseldorf type. In spite of this, the Steinheim skull is much more like modern man than the classical Neanderthalians not so much in its general form as in some special structures (temporal bone, occipital bone etc.). Therefore, the Steinheim skull, too, must have had a forerunner with more primitive characters like those found in *Pithecanthropus* and *Sinanthropus* but living in a much earlier period than that of the Riss Glaciation. All this indicates that in Europe or somewhere in the western half of the Old World, earlier than the time of Mindel Glaciation, a hominid form existed from whom the Heidelberg and Steinheim men derived their advanced characters. People who believe in *"Eoanthropus"* may now point to this form as ancestor. However, such a solution of the problem is not acceptable. The teeth of the Heidelberg mandible are human in pattern and arrangement while those of the Piltdown mandible—particularly if the canine is considered as belonging to this jaw—are undoubtedly anthropoid. On the other hand, the Piltdown braincase can, in no case, be ancestral to the Steinheim skull because it is already much more advanced than the latter. To single out only one difference in this regard, Piltdown shows no frontal torus but quite a modern supraorbital region whereas Steinheim still has heavy supraorbitals. It is interesting that even Keith (McCown and Keith, 1939) did not refer to *"Eoanthropus"* in discussing the relationship of the Mount Carmel population to the Neanderthalians. The appearance of hominids with rather advanced human features in the Middle Pleistocene of Europe remains in the dark for the present. All the facts, however, point to the probability that an ancestral, primitive hominid existed in Europe or West Asia in the Lower Pleistocene or, more probably, already in the Pliocene.

This discussion shows that the neglect of morphological features in studying the relationship of different hominid types and the attempt to replace this by geological and chronological considerations does not secure a usable solution but only leads back to morphology again. There is, therefore, no reason why the Neanderthalians should not be considered intermediate forms be-

tween primitive types like *Sinanthropus* and *Pithecanthropus*, on one hand, and *Homo sapiens*, on the other, if all morphological presuppositions point in this direction. There are no particular features which would indicate a separate development for any Neanderthal form. Not very long ago an author of the first rank, Sir Arthur Keith (1925), considered the occurrence of the so-called taurodontism in the lower molars of the Neanderthalians evidence that they had undergone unilateral specialization. The peculiar roominess of the pulp cavity, allegedly characteristic of all the Neanderthalians, was thought to be absent in anthropoids as well as in *Homo sapiens*. For this reason it was considered as a special feature, developed in fossil hominids, and neither taken over from anthropoids nor transmitted to *Homo sapiens* as—assumedly— should have been the case were *Homo sapiens* the descendant of the Neanderthalians. In my paper on the *Sinanthropus* dentition (1937b) I showed that, even at the time this feature was claimed as an example of specialization, both the former and latter suppositions were erroneous. Typical taurodontism occurs in orang-utang and chimpanzee, nor is it rare among certain races of modern mankind, as for instance Eskimo and Bushman. Moreover, all Neanderthalians do not show this feature. It is absent in the Ehringsdorf molars although the teeth of the Ehringsdorf mandible are more primitive than those of the Heidelberg mandible with its taurodont molars. I showed also that taurodontism is bound with large crowns and large roots and disappears with the reduction in size. Senjürek (1939) re-confirmed the occurrence of taurodontism in the molars of anthropoids. It is very likely that the hominids have been derived from an anthropoid type with taurodont molars. The absence of taurodontism in modern man can, therefore, in no case be construed as proof against his descent from a taurodont fossil hominid. In the meantime, Sir Arthur Keith also seems to have acknowledged the irrelevancy of taurodontism, for in his publication with McCown (1939) taurodontism is no longer referred to as a distinctive feature, although the Mount Carmel population which is expressly considered as on the way to modern man displays taurodontism in "a slight degree."

Of course, we know cases of specialization occurring in an otherwise fairly complete evolutionary line. According to Matthew (1926) *Hipparion* is not in the direct ancestral line of *Equus*, althought it is intermediate between the real ancestors, *Merychippus* and *Equus*. It is considered as a deviating "genus," because it had a separate protocone on the upper molars and complete lateral digits. Had a low connecting crest reared up between protocone and protoloph, the tooth would have been converted into an *Equus* tooth as the foot would have been the equid hoof had the lateral toes been lost. Yet these primitive characters have been retained while other forms which have also developed, as did *Hipparion* from *Merychippus*, have been transformed gradually into *Equus*.

In the case of the Neanderthalians no structural peculiarity has so far been known which was retained without undergoing any change during the movement toward modern man. All the individual features which determine the character of the Neanderthalians show evidence of such a transformation. Moreover, most of the specimens which represent special Neanderthal forms combine features of primitive character with those already modern-human. I called this occurrence disharmony. Matthew may have been right in separating *Hipparion* from *Equus* as an independent "genus." But it is significant that he also considers the direct ancestors of *Equus*, in the sequence of their appearance, as "genera" themselves, although each one of them gives rise to the one next following. *Merychippus* is a genus; *Pliohippus* is a genus; *Plesihippus* is a genus and *Equus* is a genus in spite of the acknowledged fact that each of these genera has been transformed into the next. In the vertical classification the term "genus" has a different

sense from the same term when used in the horizontal classification. If we follow the modern, taxonomic interpretation, a species is not determined by morphological facts but by geographical distribution and breeding habits. For example, two bird groups can live in the same locality—or even next door to each other—and be so similar as to be practically indistinguishable as regards morphological characters, yet be considered two species if they do not interbreed under natural conditions, although they may do so in captivity. We do not know about the breeding habits of the fossil horses but there cannot have been sexual aversion between them. For *Merychippus*, already in the state of transformation to a *Pliohippus*, has apparently interbred with others, or a true *Pliohippus* could never have been born.

I was perhaps a little too pedantic in explaining the horse case, but it proves useful when we come to man and his ancestral line. In 1939, I faced an almost solid phalanx, consisting of Le Gros Clark, Osman Hill and Zuckerman, which criticized me for using the name *Sinanthropus pekinensis* for the Peking Man, although I considered him morphologically identical with *Pithecanthropus erectus*, the Java Man. Since the name *"Sinanthropus"* implies a different genus, according to the rules of the taxonomists, this name should be dropped and replaced by the name *Pithecanthropus* if the two forms were really identical. Osman Hill proposes to adopt the principle used in zoological nomenclature and apply it in anthropological nomenclature. He says: "Generic differences involve differences in external or internal anatomical structures while specific differences involve no difference in structure." As I have shown above, Osman Hill is mistaken, and apart from that, how can we ascertain specific differences if we are only dealing with bones and there is "no difference in structure" which is decisive? Osman Hill, in his taxonomic zeal, goes even so far as to write: "It is impossible to escape the view that there are several "species" of living man, and several more fossil kinds" and seriously proposes to restrict the term *Homo sapiens* either to "white man"—in which case Mediterranean, Alpine etc. will become subspecies—or to some particular group of Europeans. Modern taxonomists consider "sexual aversion" a sufficient specific difference. Now, why not extend this to political aversion also? In recent history political aversion has assumed the form of sexual aversion (see some sorts of Whites and colored peoples, or "Aryans" and "Non-Aryans"). There is indeed a parallelism between the two bird groups which are specifically different, because they do not interbreed under natural conditions—attitude in public in the case of the human examples—but do so in captivity—private life attitude. Why then not reserve Linnaeus' name *"Homo sapiens"* for the Central European "Master-race" which certainly is a "particular group of Europeans?" I am sure that this is not Osman Hill's meaning, but it is the logical consequence of those ideas. Darwin said in 1859 that the "opinions of naturalists having sound judgment is the only guide to follow" in the determination of a species while Hooton (1931) finds that this is "a very subjective and arbitrary procedure."

A glance at palaeoanthropological nomenclature shows that the names given to the different hominid forms are not more than appellations to distinguish them from each other, even if these names have been clothed in the scientific cloak of Linnaeus' principles. They express no classificatory meaning, even if the donors of the names or those who use them believe that they do. As I have already said above, McCown and Keith range the Neanderthalians in the "genus" *Palaeoanthropus* and subdivide this genus in five "species." From the palaeozoologic viewpoint they are completely justified in doing so, because Matthew called all the acknowledgedly different forms of *Equus* "genera" and subdivided all of them into "species." But I think McCown and Keith will answer in the negative when I ask them whether they are sure that there has been a

sexual aversion between "*Palaeoanthropus ehringsdorfensis*" and "*Palaeoanthropus krapinensis*" living at the same period and at a distance of not more than 430 miles from each other.

In my earlier reply to the criticism of Le Gros Clark, Osman Hill and Zuckerman I laid stress on the fact that never, since I first wrote on the *Sinanthropus-Pithecanthropus* problem (1930)—immediately after the publication of Black's preliminary notes on the *Sinanthropus* finds,—did I leave any doubt that I considered the two forms as very closely related. I defined the relationship of both forms as representing an identical stage of evolution, especially when compared with the Neanderthalians, but at the same time I emphasized the fact that there are incontestable differences. In the preceding paragraph dealing with the relationship between the two forms I discussed the character of the divergency and came to the conclusion that it is great and constant enough to justify a certain morphological separation. The degree of divergence may correspond to one such as exists between the living races of mankind today, provided the position of *Pithecanthropus* will not suffer essential change as a result of the new discoveries to which I alluded.

I am not at all opposed to a revision of the nomenclature (cf. Weidenreich, 1940c), although I do not see any necessity for such change. I never imagined that anthropological names were tantamount to generic names or were considered as such by those familiar with the history of palaeoanthropology. When I continued to use the name *Sinanthropus* and did not drop it in favor of *Pithecanthropus* the reason was neither personal vanity nor "the tendency to make too much of such a discovery" as suggested by Zuckerman but respect for Davidson Black and his work. It would, indeed, have been rather tactless, had I begun my task as Black's successor by eliminating the name he had coined unless there were most cogent reasons. Incidentally, I may reply to Zuckerman that, whatever name may be chosen for "such a discovery" as the fossils of Choukoutien, their significance in our knowledge of the prehistory of man is so great that there is certainly no need for any exaggeration. In addition, the complete elimination of the name *Sinanthropus* and the substitution of *Pithecanthropus* would undoubtedly enhance the confusion as long as there is no general agreement as to their conformity. Even if we should now change the name to "*Pithecanthropus pekinensis*," as proposed by Le Gros Clark,—more correctly it would be "*Pithecanthropus erectus pekinensis*"—that would probably not satisfy the more genetically-minded anthropologists to whom the genus name "*Homo*" may appear more appropriate. But concede this also, it would not be correct to call our fossil "*Homo pekinensis*" or "*Homo erectus pekinensis*"; it would be best to call it "*Homo sapiens erectus pekinensis*." Otherwise it would appear as a proper "species," different from "*Homo sapiens*" which remains doubtful, to say the least. Yet to use the name "*Homo sapiens*" in this case may eventually provoke Osman Hill's protest. People more interested in facts than in logomachy will—at least I hope so—agree with me, when I continue for the present to speak of the Choukoutien fossil as "*Sinanthropus pekinensis*." I also hope that there will no longer be any doubt that I use this term in the same sense as I have always used it, namely: just as a name without any "generic" or "specific" meaning or, in other words, as a "latinization" of Peking Man.

II. SPECIAL AFFINITIES

In a recent paper Howells (1942) follows the old doctrine in considering Neanderthalian as "a species distinct from *Homo sapiens*." This argument is chiefly based on the consideration of the Australian aborigines as the most primitive of all the racial variations of modern man notwithstanding their wide difference from the Neanderthalians. So wide is this difference, ac-

cording to Howells, that the Australians could not have been the direct descendants of the Neanderthalians who must, then, have disappeared without leaving behind any descendants at all. But Howells does admit the possibility that the Australians may not be the direct descendants, although Huxley and others have suggested that they are. There is a logical mistake in those deductions. For the Neanderthalians are identified only with European Neanderthalian types and it is presumed that, if the Australians are not traceable to European Neanderthalians, *Homo sapiens* can never have passed through a Neanderthal stage.

I have made a rejoinder elsewhere (1943) to Howells' paper but confined myself there to more general questions. Howells starts from the presumption that the European Neanderthal Man represents the only form immediately preceding modern man, and the Australian, on the other hand, represents the only primitive form of the latter. This problem could not be discussed in extenso without reviewing all possible forms attributable to the modern human type. Such a task would be beyond the compass of this paper. The reader, therefore, is referred to Coon's (1939) book which deals with all the types of fossil modern man. Only some examples may be given here. But first of all, the methods we must use in distinguishing races or subspecies within a certain group of forms must be tested. We must find whether these methods are sufficiently reliable so that such a diagnosis is valid if it can only be based on morphological characters of the skull. It does not seem necessary to emphasize that there is no such method. Even the "Coefficient of Racial Likeness" is of no great help, if only one or two specimens of a fossil form and not a long series are available, as is so frequently the case. Fisher (1936) admits that the Coefficient Method is only a test of significance and calculates only a probability but not a racial difference. He even goes so far as to concede that "the fundamental problems needed for the ethnographic interpretation of cranial remains must be advanced many steps further than the present stage of knowledge before they can contribute appreciably to our knowledge of racial history." This is significant, yet it refers only to the coefficient method based exclusively on *metrical* characters. How far Fisher's obvious skepticism also applies to Morant's attempt (1930/31) to determine eventual racial differences among the Upper Palaeolithic population of Europe by means of metrical characters only, is not clear. In any case the conclusion at which Morant arrived is not guaranteed against objection. The author found "no sufficient statistical justification for differentiating the existing examples," so far as they may belong to several distinct types or races. "Local and secular varieties almost certainly existed but the differences between them must have been slight" says Morant. He claims that the Upper Palaeolithic series is rather less variable than some modern European series, considered to be racially homogenous. I believe that Morant might have come to somewhat different results had he not restricted his study to metrical characters but had extended it to non-metrical ones. For example, it is obvious that the face of the female of the so-called Grimaldi negroid represents quite another type than the face of the female of Obercassel. It is, of course, very difficult to decide whether these, and other differences, are great enough to place the individuals concerned in completely separated groups; but it cannot be denied that they may represent different races, particularly if the contrary statement has been based only on few measurable features of the skull. Moreover, even in those early days, the population of Europe may have been as mixed as it is today. In that case the greater homogeneity may not be a true but a seeming one and not typical of the Upper Palaeolithic population of the whole world.

In judging morphological differences among fossil forms of modern man, particularly when distinguishing them from the Neanderthalians and their variations, it should never be forgotten

that forms in the process of evolution are being compared with relatively static ones: Metrical characters changing as the result of this evolution—and many of those employed by Morant belong to this category—can only be applied with considerable reservation. Characters in phylogenetic change and those of racial differentiations may overlap and obscure the latter process.

As has been shown in preceding paragraphs, *Sinanthropus* differs from *Pithecanthropus* in characters which have not so much phylogenetic as "racial" bearing. On the basis of the analysis of the morphological characters it was also shown that *Homo soloensis* is more closely related to *Pithecanthropus* than to *Sinanthropus*, although *Homo soloensis* represents a form phylogenetically more advanced than *Pithecanthropus* from which he inherited his general and specific features. On the other hand, *Homo soloensis* is, to a certain extent, the equivalent of the European Neanderthalian for he represents a similarly evolutionary stage as the latter, although he is not identical with him. Looking for a modern human form which could pass as a possible descendant of *Homo soloensis*, one finds the Australian aborigine. Unfortunately, the three skulls which are considered by the authors as representatives of an Upper Palaeolithic stage of the Australian native—the Wadjak, Talgai and Cohuna skulls—cannot be assigned to a geological age with any certainty. This is particularly true of the Wadjak Skull (cf. Weidenreich, 1942). None of the skulls is complete: all are crushed, especially the Talgai skull. There is neither conformity in general forms nor in dentition. Nevertheless, the skulls do have in common: heavy, far-projecting superciliary ridges; flat, receding foreheads; deep infraglabellar notches and more or less well developed maxillary prognathism. Keith (1931) concludes as follows: "the correspondence between the Talgai and the Cohuna skulls is so exact that I have no hesitation in assigning both of them to the same race. . . . Both skulls represent the proto-Australian type out of which the modern aboriginal type has been evolved." As to the Wadjak skulls Keith (1925) is less definite: "to make the Wadjak type into the Australian needs an extensive reduction in all parts, and when this is done, there remain so many points of difference that we cannot regard their relationship as more than a cousinship. . . . Proto-Australian is not the right name for the Wadjak man; he is related to the Talgai or Australian type and he is related to the Rhodesian type." Pinkley (1936) suggests that "the close resemblance (of the Wadjak man) to the Australian is due to the primitiveness of his skull structure—a cousin rather than an ancestral relationship" and that "the Mediterranean race could have more directly derived from the Wadjak type than could those of other living races." But Pinkley adds that "these statements must be taken only as a tentative hypothesis and not as an emphatic claim of Wadjak ancestry for the Mediterranean race." Such cautious formulation is certainly justified. I made no special examination of the Wadjak remains but the face of Skull I certainly resembles, in its general appearance, much more that of the "Melanesoid" woman of the Upper Cave of Choukoutien (Figs. 267 and 268 B) than any living representative of the Mediterranean race. But much more important than any precise analysis of the special racial characters of the pre-Australian skulls—so far at least as the Talgai and Cohuna skulls are concerned—is the fact that their difference from Upper Palaeolithic European man is in the direction of the living Australians or Melanesians and not in the direction of the modern Europeans.

When, however, these skulls and those of modern Australian natives are compared with *Homo soloensis* the likeness is surprising, after due allowance is made for the fact that the Australian is further developed phylogenetically than is *Homo soloensis*. In Figure 264 C the skull of an Australian (No. 792) is depicted. This attracted Burkitt's and Hunter's special attention

(1923) because of the primitive character of the frontal and occipital regions. When this specimen is compared with the Ngandong Skull V, the latter being reduced to the same length, the only difference is the greater height of the modern skull and the more pronounced vaulting of the vertex region. There is, however, no great divergence in the cranial capacity which amounts to 1255 cc. in the Ngandong and 1211 cc. in the Australian. But there is considerable difference in the maximum length: the Ngandong skull measures 219.5 mm. while the Australian has a length of 203 mm. In spite of its modern form the Australian skull shows well-developed superciliary ridges; a flat, far-receding forehead; a prelambda depression; a torus-like demarcation line between occipital and nuchal plane and, finally, a sharp bend between the upper and lower scales of the occipital bone. In addition the pterion region reveals a short sphenoparietal articulation measuring only 5 to 8 mm. The infraglabellar notch is deep and narrow as it was, apparently, in the Ngandong Skull V.

A comparative mid-sagittal craniogram with the nasion-opisthion line as base is also very instructive. In Figure 266 the craniograms of the Ngandong Skull I, the Rhodesian Skull, the Australian Skull No. 792, and the male skull of Obercassel have been superimposed on this line at the nasion, all reduced to ⅔. All four skulls have about the same basal length: it is the smallest in the Ngandong Skull (142 mm.); the greatest in the Rhodesian Skull (149 mm.); while the two modern-human skulls—Australian and Obercassel—show about the same measurement (145–146 mm.), thus exactly ranging between the two extremes. The Ngandong, Rhodesian and Australian skulls exhibit a gradual increase in height corresponding to their respective positions in the line of evolution. The vertex height has risen from 106 mm. and 113 mm., respectively, to 127 mm.; the frontal inclination angle II has risen from 56° and 60° to 70°. Nevertheless, the character of the frontal and occipital bones has remained the same in principle. This becomes strikingly apparent when the craniograms of the three skulls are compared with that of the Obercassel Skull. The male skull of Obercassel is one of the largest of the European Upper Palaeolithic skulls. It has thick bones and rather pronounced supraorbitals, similar to those of the male skull of Předmost. As a modern-human type, the Obercassel skull on the whole is equal to the Australian No. 792 skull with which, indeed, it is identical in absolute and relative height (127 mm. against 145–146 mm. basal length; 87.3 length-height index above n-o.) Nevertheless, the character of the frontal and occipital bones are quite different. In spite of the fact that the frontal inclination angle II of the Obercassel skull is only 2° greater than that of the Australian, the frontal bone of the former is much more erect and vaulted and the supraorbitals much less prominent than in the latter. The differences of the occipital bone are still greater: the Obercassel occipital is much more erect and the inion region much less protruding; in addition, there is no sharp bend between the upper and lower scales. In one word, the Australian skull still shows the pattern of the South East Asiatic *Pithecanthropus-Homo soloensis* line while the Obercassel Skull shows that of the European Steinheim-Ehringsdorf skulls. The original, special feature of the *Pithecanthropus-Homo soloensis* forehead (flat, prone squama ending in big, protrucing suprafacials above a deep infraglabellar notch) has undergone very little change despite the fact that the skull as a whole has been transformed into the modern-human pattern. Even in living Australians this ancient heritage is ·occasionally recognizable, as Figure 265 demonstrates.

It can be gathered from this brief review that at least one line leads from *Pithecanthropus* and *Homo soloensis* to the Australian aborigines of today. This does not mean, of course, that I believe all the Australians of today can be traced back to *Pithecanthropus* or that they are the

sole descendants of the *Pithecanthropus-Homo soloensis* line. But it seems clear that typical Australians have evolved from Neanderthaloid forms, although there may not be direct kinship between them and the European type of La Chapelle-aux-Saints or others of his kind.

In discussing the similarity between the Australian No. 792 and *Homo soloensis* (Fig. 266) reference was made to the Rhodesian Skull. In the preceding paragraphs it has already been indicated that this skull is to be considered as a representative of a phylogenetically low group of Neanderthalian forms, divergent from the classic Neanderthalians as well as from the more advanced "Ehringsdorf Group." There is small doubt that the type of Rhodesian man is closer to that of *Homo soloensis* and, consequently, also to his descendants, the Australians, than he is to the European Neanderthal forms and their descendants. Unfortunately, no complete face or characteristic facial bones are preserved of either *Pithecanthropus* or *Homo soloensis*. Yet the enormous size of the palate and the robustness of the alveolar portion of the maxilla displayed by Pithecanthropus Skull IV (Fig. 248) have their only equivalent, thus far, in the Rhodesian and the Wadjak Skulls. That there must be some closer relationship between the two last mentioned types has been stressed by many authors (Keith, 1925; and others). But we have to look for an eventual relationship of the African Rhodesian first of all in Africa itself. Drennan (1937) considers the Florisbad Man as an African variant of the Neanderthal race and arrived at the following conclusion: "in Florisbad Man, Rhodesian Man and the Cape Flats Australoid we have a closely related phylogenetic sequence linking the *Homo primigenius* to the *Homo sapiens* type." Keith (1937/38a) regards the Florisbad type as a transitional form leading from the older Rhodesian type to the later Boskop type. Galloway (1937/38a) is not so definite as to the exact position of the Florisbad skull. According to him, Florisbad Man is more modern than Neanderthal Man and arises "from some separate but closely related stock nearer in cerebral development to Rhodesian Man." But "Florisbad Man could serve equally well as the ancestor of Boskop Man and the proto-Australian stock of Wadjak." But Boskop type still persists among the living South African races according to the same author (1937/38b).

It is at this moment, in view of the defective condition of all the finds, impossible to arrive at really conclusive results concerning the exact relationship of the different types in question, but one conclusion is inescapable, namely: Neanderthaloids also existed outside of Europe, and these Neanderthaloids are linked to the living populations of the various regions by forms intermediate in character. This seems probable in the *Pithecanthropus—Homo soloensis*—Australian line and in the Rhodesian—Florisbad—Boskop—South African line. McCown and Keith (1939) consider the Skhūl population of Palestine as a mixture between Neanderthal elements of the "Ehringsdorf Group" and *Homo sapiens*, but they do not identify this *Homo sapiens* form with the Cro Magnon of Western Europe. Rather, the authors expect that remains of true proto-Cro Magnons will be discovered still farther to the East. Their reservation, however, does not alter the main issue, that: (1) We now have evidence of the direct transformation of the Neanderthaloid forms into *Homo sapiens;* (2) The Neanderthalians need not be considered as having become extinct without having left any descendants behind; (3) Racial or regional differentiations are recognizable within the Neanderthalians themselves and can be traced from there to races of modern mankind.

A continuous line leading from *Sinanthropus* to modern man has not been discovered, although representatives of Upper Palaeolithic *Homo sapiens* have been found in the cave just atop the hill of Choukoutien, now called the "Upper Cave" of Choukoutien (cf. Weidenreich, 1939b; Pei, 1939b; 1940). As the culture and fauna of this cave prove, the "Upper Cave" re-

mains must be attributed to the Late Magdalenian (Pei, 1939b; 1940).   The human skeletons, therefore, are directly comparable with those of Chancelade and Obercassel which belong to the same period.   The three best preserved and almost complete skulls are those of undoubtedly modern type (Figs. 267 and 268), but the surprising fact is that none of them looks like a typical Mongol and that each differs from the others.   This unlikeness between the three skulls is all the more striking, because they apparently belonged to the same family, a matter discussed in my earlier paper (1939b) where the reader will find pictures and measurements of those fossil skulls as well as modern skulls with which they may be compared.   The three skulls (Figs. 267 and 269) are of different sex and age.   Skull No. 101 (A) is that of a male of rather advanced age ("Old Man"); most of the cranial sutures are completely fused.   Skull No. 102 (B) is the skull of a relatively young female; the basal suture being open, third molar not yet errupted.   Skull No. 103 (C) is the skull of a female but older than individual B.   As to the racial affinities, the female, B, shows the greatest similarity to Melanesians of today.   For this reason I have designated the type as "Melanesoid."   Female, C, most resembles the Eskimo of today; therefore, I have designated the type as "Eskimoid."   The skull of the "Old Man," A, is however difficult to classify.   This skull undoubtedly shows great likeness to the skulls of European Cro Magnons, in particular the Obercassel type, and the Palaeolithic Mechta race of Algeries which, however, shows both heavier and broader face.   But there are other differences when the skull is looked at from the side (Fig. 268, A).   The Choukoutien skull has a pinched nose, a pronounced alveolar prognathism combined with a strongly convex nasoalveolar clivus, and the cheekbones are oriented in a vertical plane which is directed forward more than is the case in the European Neanderthal skulls.   When the midsagittal craniogram of the skull (Fig. 266) is compared with that of the Obercassel male (Fig. 266), it becomes evident that the Choukoutien skull follows more the pattern of the Rhodesian—Australian group, so far as configuration of the frontal and occipital bone is concerned.   These are the reasons why I regard the "Old Man" of Choukoutien as an early East Asiatic type, and, as some pre-historic Mongols reveal similar characters, I have classified him as a proto-Mongoloid.

Despite all this we look in vain for special features which might indicate a closer relationship between *Sinanthropus* and the population of the "Upper Cave" of Choukoutien.   Therefore, it seems at first glance that no such line leads from *Sinanthropus* to any special racial group of the Far East as has been described above in the case of *Pithecanthropus*.   But such a conclusion would be too hasty.   There can be no doubt that some of the most characteristic features of *Sinanthropus* are found again in certain branches of mankind of today.   In my paper on the *Sinanthropus* population (1935) I called attention to the fact that some of the *Sinanthropus* mandibles possess a typical mandibular torus and have the upper incisors, particularly the lateral one, pronouncedly shovel-shaped.   Both particularities are found in the Mongolian races of to-day in a much higher percentage than in other races.   In my paper on the *Sinanthropus* mandible (1936b) and that on dentition (1937b) I reverted to this question and discussed it exhaustively (See also the chapter above dealing with maxillary exostosis).   There is, therefore, no reason for returning to the facts themselves.   In the paper on the limb-bones of *Sinanthropus* (1941a) I have shown that humerus as well as femur are not only human in their entire appearance but come very close to modern man in their general character.   However, there are certain features which alone or in combination with others show special affinities to certain racial groups, although these features may be found far-spread over the world.   The peculiarities are extreme platymeria of the femur and a very strong development of the deltoid tuberosity.   Platymeria

occurs in all main races and is especially frequent in Neolithic femora of Europe. But it shows a strange predilection for certain groups of Neolithic and Prehistoric Mongolian types of North China. It is, furthermore, characteristic of the Tsitsihar population and in particular of that of Kansu, although it is entirely absent in the Yang Shao population living at the same time as the Kansu people and not very far from them. The Kansu population has also the same strongly developed deltoid tuberosity as *Sinanthropus*, but its facial skeleton already shows typical Mongolian character (Davidson Black, 1928). The same combination—pronounced platymeria and strong deltoid tuberosity—is found in the Fuegians of today where these features are so spectacular that their occurrence is expressly noted and illustrated in R. Martin's report of the morphological characters of the Fuegian skeleton (1894). It cannot be considered a matter of pure accident that this same combination which seems without any inherent connection occurs in *Sinanthropus*, in the pre-historic Mongolian group of Kansu and in the Fuegians of today.

The *Sinanthropus* calvaria has other features which are equally significant for the point under discussion. The first is the sagittal crest. Although its character is somewhat changed in modern skulls, it is typical of Eskimo and Amerindian skulls and also occurs frequently among the North Chinese population of today (See Weidenreich, 1939a; Pl. III, Fig. 17). The crest, however, is not confined to these groups, it is found also in other modern racial groups, particularly in Melanesians and Australians. On the other hand, it is characteristic of the Rhodesian Skull and very pronounced in *Pithecanthropus* Skull IV. These occurrences indicate that the crest has been transmitted from one common ancestor to *Sinanthropus* as well as *Pithecanthropus* (cf. chapter above, dealing with the architectonic structure of the *Sinanthropus* skull), and has been passed on to their descendants with the result that it is now found in races as far apart geographically as the Amerindians and Tasmanian-Australians of today. Giuseppe Sergi (1928) made a great story out of the "Lofocephali" and their migrations around the world. Of course, at that time he could not know that the homeland of these "crested" races was neither in America, as he at first supposed, nor in Africa, as he assumed after the discovery of the Rhodesian Skull, but rather somewhere in South East Asia. In any case, the sagittal crest is completely absent or at least extremely rare in whites and typical negroes and has, so far, never been found in European Neanderthalians or Upper Palaeolithic man.

A second feature of the *Sinanthropus* calvaria which shows certain racial affinities is the "os Incae." While the sagittal crest occurs in every *Sinanthropus* specimen so far recovered, this intercalary bone is present in three to four (out of five) skulls where the occipital region concerned is preserved. In other words, it is present in 60 or 80 per cent, a much greater percentage than in any living race. Because confusion has resulted from the inability or difficulty of distinguishing between the ossa epactalia and the "ossa Incae," statistical figures dealing with the occurrence of the occipital intercalaria are not reliable. This is particularly true of R. Martin's list (1928) which is full of mistakes. According to Anutschin (1882/83) the Inca bone is eight and a half times more frequent in Amerindians than whites. Frank Russel (1900) found it in 15 per cent of the Amerindians, but Le Double (1903) in only 3.1 per cent of the whites. P. Bartels (1905) gives the following figures for the os Incae (every kind of bone, including divided ones): Mongols, 3.7 per cent; Bushman and Hottentot, 7.1 per cent; Shilluk 5.8 per cent; Egyptian mummies 3.7 per cent; ancient Peruvians, 5.1 per cent; New Britain and New Ireland natives, 10.0 per cent. In Chinese, Malayans, Australians and Tirolians Bartels found no Inca bones. Since however Bartels list is not limited to the "os Incae verum" but also includes any partititon of the occipital squama, it is of little value. His figure of 10 per cent for the New Britain and New Ireland na-

tives is so high that I checked these in the American Museum of Natural History (New York). Separating the New Britain from the New Ireland material, I found no "os Incae verum" in 116 New Britain skulls, an "os Incae tripartitum" in only one case, and an incomplete os in an additional one. Of New Ireland material only 13 skulls were available but in no case was an "os Incae verum" found, but in one case an "os Incae tripartitum" and in another case an incomplete one. This check represents a total of 129 skulls whereas Bartels refers to 50 skulls only. The native skulls of New Britain and New Ireland possess, therefore, no true "ossa Incae" unless the divided bones are counted as true ones, and the percentage of occurrence is 1.55, not 10.0 as reported by Bartels and Martin. The "os Incae verum" therefore must be considered as a peculiarity found only in certain races of modern man; among them it occurs in high percentage only in certain Mongolian groups.

The facial skeleton of *Sinanthropus* shows several special features which occur in modern races and, once again, to those belonging to the Mongols particularly. These features are: (1) Broad nasal bones with small differences between upper and middle breadths (see no. 86 in the analysis list). (2) Profile contour of the nasal saddle agrees most closely with that of the Amerindians, Eskimo and Australian aborigines (see no. 87). (3) The profile angle of the nasal roof amounts to 89°; this is a little above the average of the Mongolian racial groups which show a higher average than all other races (see no. 88). (4) The malar facies and the frontosphenoidal process of the maxilla display pronounced frontal orientation, their inclination angle amounting to 50°. The same angle is 55° to 57° in the Eskimo while there is a much smaller angle in Europeans and Melanesians (cf. nos. 102–104). (5) The infraorbital margin is rounded and even with the floor of the orbit, a very common feature among the Mongols of today (no. 116).

To these Mongolian traits of *Sinanthropus*, two additions can be made which, according to authorities, occur chiefly in Mongolian races. These are the buccal exostosis of the maxilla and the exostosis of the external auditory meatus. Both structures have been exhaustively described above. .The buccal maxillary exostosis is found in all three upper jaws of *Sinanthropus* available so far. If, in so few cases, an estimate of percentage is allowable this is 100 per cent. Hrdlička (1935) found this exostosis in 2.5 per cent of Siberian crania and in 4.5 per cent of the crania of Koniags and Aleuts. Schreiner found it in 3.9 per cent of the crania of Lapps, and Murakame in 5.2 per cent of Japanese. There are no data available regarding its occurrence in other races.

The ear exostosis appears in two different forms: (1) as a general thickening of the tympanic plate easily visible at the free lateral edge and (2) as a special outgrowth situated upon this border or, more frequently, upon the anterior or posterior borders within the meatus. The general exostosis obvious in *Sinanthropus* is found chiefly among Eskimos and Amerindians. The special exostosis is exhibited by Sinanthropus Skull X only and is the sole instance of such occurrence among fossil hominids. It is found, according to Hrdlička (1935), in all modern races but only to the extent of 18–20 per cent in Polynesians and 12–30 per cent in Amerindians while it is extremely rare in whites.

The peculiarities of the *Sinanthropus* skeleton, to sum up, are neither "adaptive" nor have they any recognizable connection with special functions which could not be performed otherwise. Their transmission to *Homo sapiens* corroborates first the thesis that *Sinanthropus* is a direct ancestor of *Homo sapiens*, and secondly, that there is a closer relationship to Mongols—or at least to certain Mongolian groups—than to any other races, particularly to whites. This statement does not mean that modern Mongols derived exclusively from *Sinanthropus* nor that

Sinanthropus did not give origin to other races. In any case, it is safe to say that racial groups supplied with those peculiarities have *Sinanthropus* in their ancestry. Had only one character been transmitted, the relationship might be questioned, but as there are *twelve* special features which behave in the same way the coincidence cannot be accidental.

In discussing, above, the mandibular torus, I mentioned that Hrdlička (1940) denied any racial quality to this feature for the reason that it occurs in almost all races of modern mankind. This, however, is not the point. Whether a certain feature should be considered as a racial character does not depend on the occurrence as such, but on its frequency. According to Hrdlička's own statistics (see Table XVI), the torus is completely absent in Melanesians, rises to 16.7 per cent in Australians, is found in 40 per cent of Alaskan Eskimos, in 61.8 per cent of Koniags and Aleuts and in 83.3 per cent of Lapps. Such a predilection for certain racial groups offers, of course, no explanation of the nature of the structure but it is undoubtedly an indication of an eventually closer relationship. That one or the other special *Sinanthropus* feature may occasionally be found in racial groups having no further connection cannot be used as an argument against such relationship. We know very little about the history of races. Schreiner (1931/35), for example, denies that the occurrence of the mandibular torus in c. 12 per cent of the present-day Norwegians can be interpreted as an earlier mixture with the Lapps, although, according to his own investigation, this percentage rises up to 24 per cent in the Norwegian population of the Middle Ages. How can Schreiner be sure that there was not more extended interbreeding in early times? If a character is dominant, it can be transmitted by very few individuals even to a larger population of different racial structure. I am sceptical about too wild speculations on the distribution of the blood groups and deductions therefrom concerning the relationship of different groups of modern mankind, but it may be that in morphological characters we are dealing with similar conditions. If special characters are found massed in some regions, sporadically distributed in others and completely lacking in still a third place, the reason for such irregular distribution may be a double one. The character may have been peculiar to a common ancestor and retained in one group of descendants while it was more or less lost in other groups. Or, the character may have developed in one group and been transmitted to other groups by secondary interbreeding: in such a case the effect may depend on the number of infiltrating individuals or on the genetical quality of the character.

To come back to the issue. So far as *Sinanthropus* is concerned, no intermediate Neanderthaloid phase has been discovered which links him to *Homo sapiens* in general or to certain racial differentiations. But there are clear evidences that *Sinanthropus* developed into *Homo sapiens* and particularly that he has merged into certain Mongolian groups. In the case of *Pithecanthropus*, the evolutionary line leads through *Homo soloensis* to the Australian aborigine. In the case of Rhodesian Man who represents a stage already more advanced than that of *Sinanthropus* or *Pithecanthropus* the line leads to certain South African races of today. Neanderthalians of the European type reveal closer relations to the whites via the Skhūl population of Palestine.

It can be inferred from all these data that *Homo sapiens*, as represented in his variant racial differentiations, took his origin from primitive hominids, themselves already showing signs of specific variations which may be interpreted as of racial or regional character. These primitive races may be homologized to modern races merely by the common possession of peculiar characters. Since the hominids entered the higher stages of evolution further differentiations within the group and permanent intermixture with others have certainly taken place. So far, our knowledge of the dawn of those races which can be identified with modern ones is very poor.

The "Upper Cave" population of Choukoutien may be cited as an example. As mentioned above, of the two female skulls one (Figs. 267 and 268 B) looks like a Melanesian of today, the other (Figs. 267 and 268 C) like an Eskimo. But to identify them with those races would not be justified. Their designation as "Melanoid" and "Eskimoid" means merely that those features we consider as typical of those races were already developed in the Far Eastern Palaeolithic man of Late Magdalenian. Another striking fact is that individuals with racial characteristics as found today in such widely separated areas as Melanesia and arctic America were at that time members of the same family dwelling in a cave in North China (cf. Weidenreich, 1939b). That Eskimoid types should be found in North China is not surprising, for the Eskimo came from North East Asia where Eskimo types are still characteristic of a certain part of the population. Melanesoid types, so far toward the north of Asia, has not yet been discovered but Mansuy and Colani (1925) and Fromaget and Saurin (1936) described skulls of "Melanesoid" appearance from the Lower Neolithic of Lang-Cuom and the Mesolithic of Tam-Pong in Indo-China. The "Old Man" of the "Upper Cave" of Choukoutien cannot be identified, with certainty, with any Asiatic race but there is undoubtedly some similarity to prehistoric and modern Mongols. The strange fact that the only three completely preserved skulls should represent three racial types can be explained in three ways: (1) Those races had differentiated long before, and their representatives met by mere chance in Choukoutien. (2) In those early times racial differentiation took place in the form of great individual variations which became fixed afterward by migrations and isolation. (3) Both alternatives went hand in hand. The fact that, despite divergence in details, the three faces of the skulls are very similar lends support to the second and third possibilities.

One of the greatest obstacles to a general agreement regarding the origin of "*Homo sapiens*" are difficulties which rise from geological dating. According to W. C. Pei (1939a), *Sinanthropus* and *Pithecanthropus* lived in the Interglacial Günz-Mindel or Mindel Glaciation. This would make them contemporaneous with Heidelberg Man in Europe who, according to Zeuner (1940), belongs to this period. However, the Heidelberg mandible carries teeth which differ only slightly from those of modern man. The ancestor of Heidelberg Man whose teeth must have been as primitive as those of *Sinanthropus* must, consequently, have lived at a much earlier time—probably even in Upper Pliocene. Such an early development of the European hominid branch is the more likely because the European Neanderthalians of the Interglacial Riss-Würm (represented by the Steinheim and Ehringsdorf skulls) were already much more advanced than *Homo soloensis* of Java who is attributed to the Middle or even to the Upper Pleistocene (cf. H. de Terra, 1943). Therefore, if the European hominid line leads from Heidelberg Man to the European *Homo sapiens* (regardless of the possibility that the latter may have evolved somewhere in Asia or Africa) the branch, as such, must either be older or its later development must have been somehow more retarded than is the case with the South East Asiatic line which led to the present Australian aborigines. Colbert (1942) believes that *Sinanthropus* as well as *Pithecanthropus* did not appear in Asia earlier than Middle Pleistocene. If this is so, the retardation of the Asiatic hominids (or rather the advance of the European ones) would still be more pronounced. As compared with the European the Australian must then be regarded as a younger branch of modern mankind and, for this reason perhaps, as not having yet achieved so much as the Europeans of today. In other words, the Australian aborigine seems to be in a stage of evolution which may correspond to that of the CroMagnons who lived in the Late Pleistocene of Europe. Therefore, the Australians are not relics of earlier stages of human evolution driven from Europe

and marooned in Australia where they were conserved as were the marsupials (an idea to which most anthropologists adhere), but are representatives of the youngest of the human branches, relatively little mixed with other branches as a result of their isolation at the verge of the habitable world.

The seeming anachronism that classic Neanderthal Man lived later in Europe, in spite of being a more primitive than the more advanced Ehringsdorf group, can be explained by the arrival of the Würm Glaciation. This drove the group into neighboring regions free from ice and brought with it a more arctic form possibly better adapted to the new environmental conditions.

Let us make three assumptions as suggested by the data at hand. (1) Human evolution was not limited to a certain geographical center but went on over a vast area comprising, possibly, the entire Old World. (2) There was always great variation with a tendency to racial differentiation. (3) This process of human evolution and racial differentiation went on over a long period of time starting in the middle Tertiary and ending in the Upper Pleistocene, interrupted for longer or shorter intervals possibly by changes in the environment. Granted these assumptions, all available facts can be fused into a harmonious concept of human evolution. We do not need to explain discongruencies in time and space by resorting to side branches when there is no irrefutable evidence that evolution has gone this way. The hominids have formed—and still form—one family or, in a strictly taxonomic sense, *one* species and are all more or less related to each other in spite of manifold regional variations.

III. THE PRINCIPLES IN THE EVOLUTION OF THE HUMAN SKULL

In Part II of this paper I have discussed the changes which the hominid skull undergoes as it proceeds from the *Sinanthropus-Pithecanthropus* stage to that of modern man, so far as these changes may be deduced from the different skull forms and from individual features.

The mid-sagittal craniograms of the *Sinanthropus* Skull compared with that of a modern European of a hyperdolichocranial type (Fig. 221) and the interporial coronal craniograms of the same skull compared with those of a modern hyperdolichocranial Australian and a hyperbrachycranial European (Fig. 195) demonstrate the principle in the changes of the general form of the skull. The original low, relatively long, broad-based calvaria became transformed into a higher, shorter and narrower one. In other words, the braincase assumes a more globular form rolling itself up about a transverse axis which passes, approximately, through the ear-openings. Accordingly, the occipital foramen takes a more central position. The process can be described as a general expansion of the cranial cavity with the individual bones which build the vault turning about their respective basal axes. A real increase of bony substance to fill the growing gap is recognizable in the squama of the temporal bone, in the greater wing of the sphenoid and in the entire parietal bone which represents the central element of the calvaria. The shortening of the base in longitudinal and transverse directions is shown in the upward course of the klition and porion, a result of the increase of the basal deflection which takes place in the sphenooccipitale. The only bone of squamous character which undergoes an essential change in its general form is the occipital bone: the angle formed by the upper and lower scales becomes wider and the curve flatter. Of the bones which form the base of the skull the tympanic plate and the pyramid are the most involved. These are compressed between the parts anterior and posterior to the transverse axis with the result that the tympanic plate assumes a more vertical position and the whole pyramid is raised toward the interior of the skull.

As expansion progresses, the braincase loses its massiveness. Its walls and also the bones which form the base—tympanic plate and pyramid—reduce and become thinner. The latter decreases in all directions, its basal portion becomes increasingly spongy and its apex disappears, its place being taken by the foramen lacerum. The original massiveness of the hominid skull is manifested not only by thick walls but also in the development of a special reinforcement-system of which the frontal and occipital tori are an integral part. Architectonically, they represent superstructures forming buttresses against the thrust of the chewing pressure and the strain of the masticatory and cervical muscles. They are the larger and stronger the mightier and bulkier the masticatory apparatus and the smaller the braincase on which they are based.

The sizes of face and braincase are closely correlated, too. The larger the jaws the smaller the braincase and, conversely, the smaller the jaws the larger the braincase (Figs. 203 and 221). *Sinanthropus* has a relatively small braincase and a large face; modern man a large braincase and a small face. The reduction of the face, apart from the lessened strength of the bones themselves, is manifest in a decrease of length, height and breadth. Of these, the decrease of length, particularly along the prosthion-basion and incision-basion lines, is the most conspicuous. In this decrease of length the reduction of the alveolar processes of maxilla and mandible plays an essential rôle, and their reduction is again connected with the reduction of the crowns and roots of the teeth. The portions of the jaws above and below the alveolar processes, respectively, also participate in the general reduction but to a much less extent. This is the reason why the nasal bridge, the anterior nasal spine and the chin appear as the most prominent features of the recent human face.

Owing to the reduction of the masticatory apparatus and the expansion of the braincase, the superstructures disappear bit by bit so that now the braincase and not the superstructures determine the form of the calvaria. All the changes in metrical and non-metrical characters taking place in the individual bones (as described in Part II) can be traced back to this fundamental correlation between braincase and the masticatory apparatus. In my paper on the rôle of the brain (1941b) I was able to show that the size of the braincase is determined by the size of the brain while the size of the masticatory apparatus corresponds to the size of the body: both sizes can be represented by their (respective) weights. Size or weight of body and size or weight of brain are in inverse proportion to each other. Small animals have relatively larger brains than large animals and vice versa. This fact has been known for a long time. What has escaped attention is the fact that a relatively large brain enclosed in a small skull needs a much larger room than a relatively small brain enclosed in a large skull. The calvaria of dwarf animals look therefore, like globes composed mainly of the braincase while the maxilla appears only as a minor appendage. In large animals, however, the face, as represented by the maxilla, is the most conspicuous part of the skull, the braincase proper being almost completely hidden under the superstructures, sometimes enormously developed. In Figures 269 and 271 the skulls of three domesticated dogs of varying sizes are depicted. Skull C represents one of the smallest dwarf dogs; Skull A one of the largest dogs. The skulls A and B have been reduced to the biauricular breadth of the smallest skull (C). The shading indicates the extension of the cranial cavity in all three cases. The average body-weight of such a dog as A amounts to 38,000 g. and the brain-weight averages 107 g.: in other words, 1 g. of brain-weight corresponds to 355 g. of body-weight. The average body-weight of a dog as C is 1600 g. and that of the brain 51 g., that is: 1 g. of brain is correlated with 31 g. of body. In Figure 273 the skulls of a wild cat and a lion are compared the latter skull having been reduced to the total length of the former, shading again indicating

the extent of the cranial cavity. The body-weights are 200,000 g. for the lion and 3,300 g. for the cat. The brain-weights are 200 g. for the former and 31 g. for the latter. In other words, 1 g. of brain corresponds to 550 g. of body in the case of the lion and to 110 g. in the case of the cat.

In the anthropoid-human line the same differences exist. Modern man corresponds to a dwarf anthropoid while gorilla represents the large type. Of course, as compared with the dogs, man cannot be considered a dwarf, but that is not the point in this parallel. The point is the influence of an enlarged brain on the conformation of the skull. In man this enlargement is not a relative but a real one. Yet the effect is the same—the cranial cavity occipies much more space than it does in a smaller-brained skull, and face and superstructures, consequently, undergo corresponding reduction. In Figures 270 and 272 the skull of a male gorilla (A), the skull of the reconstructed *Pithecanthropus* Skull IV (B) and the skull of a modern, male European (C) are placed side by side, the shading indicating the extension of the cranial cavities. In the case of such figures as are depicted the brain-weight of the gorilla would amount to 450 g. and the body-weight to 135,000 g., while the brain-weight of man would be 1400 g. and his body-weight 65,000 g. In gorilla 1 g. of brain correlates with 300 g. of body-weight while in man 1 g. of brain is matched by 46 g. of body. Of the corresponding figures for *Pithecanthropus* IV the brain-weight can be estimated. This may have amounted to 850 g. There are no indications whether the body-weight came closer to man or closer to gorilla. In either case that would considerably affect the brain-weight–body-weight ratio.

Doubtless the morphological transformation the hominid skull underwent in the course of evolution can be explained as an immediate consequence of the absolute increase of the human brain. But it must be stressed that this increase, in itself, cannot have caused the special kind of transformation of the skull. The cranial capacity of some of the Neanderthalian skulls considerably exceeds even that of the average modern man. Yet their superstructures (frontal tori) have not disappeared: neither has a chin developed. Those disharmonies, as I have called them, can be found throughout human evolution. But it would carry me too far afield to speculate on their courses at this point. I only wish to point out that the expansion of the hominid brain is not a mere general inflation but proceeds in a distinct direction. The stem of the brain becomes more and more deflected the more the brain ascends toward its "vertex," or the more the lobus paracentralis becomes the vertex of the pallium. This tendency is connected with the uprolling of the skull and its consequences.

In the issue of MAN for November-December 1942 (Vol. 42), A. K. (Sir Arthur Keith) reviews my paper on "The brain and its rôle in the phylogenetic transformation of the human skull" under the heading No. 78. I am sorry that I was unable to explain clearly the somewhat complicated relations indicated above. Even A. K., apparently, did not understand the salient point, as his final remark proves. He says: "We are left wondering why the gorilla—the biggest brained of living anthropoids—has also the biggest teeth and jaws." Although the answer to this question is very simple and exhaustively given in the quoted paper, I repeat it here. The gorilla has the biggest teeth and jaws, although it has the largest brain of all the anthropoids, for exactly the same reason that the elephant possesses the largest and heaviest teeth and jaws, although it has the largest brain of all the land mammals. According to E. Dubois (1914), the body-weight of the elephant amounts to 3,048,000 g. and the brain-weight to 5,443 g., or 1 g. brain to 560 g. of body. As to the gorilla, it has indeed the largest brain of all living anthropoids. If females only are taken into account the brain-weight totals 430 g. in gorilla, 345 g. in orang-utang and 355 g. in chimpanzee, according to A. H. Schultz (1941). In the same individual cases the body-

weights are 75,000 g., 37,000 g., and 41,000 g., respectively. In female gorilla 1 g. of brain corresponds to 175 g. of body; in the female orang-utang 1 g. of brain to 107 g. of body; and in female chimpanzee 1 g. of brain to 115 g. of body. In the case of males the corresponding figures are about 300, 180 and 120 g. This explains why the gorilla has the biggest brain and the biggest teeth and jaws and why the female gorilla has smaller teeth, smaller jaws and also smaller skull superstructures than the male. Not the absolute but the relative size of the brain is what counts.

The principle which determines, in this way, the phylogenetic transformation of the human skull is not limited to the hominids, but governs all skull transformations wherever similar conditions exist. The differences between the skulls of the pigmy chimpanzee and that of the normal-sized one are of the same kind, although they are not as great as those between gorilla and man. In the dwarf and large dogs where the divergence of body-size is much more pronounced the differences of the skull-form correspond to those of man. The teeth of the King Charles spaniel are not only reduced in size but their pattern is simplified. This is the case in modern human teeth, too, when they are compared with teeth of more primitive types of man or with teeth of anthropoids. But although small and large races of dog are subjected, in principle, to the same changes as small and large anthropoid types, the fundamental character of the respective orders remains unaffected. The transformation of the human skull takes place within the limits of an anthropoid group; the simplified teeth of modern man still show the general anthropoid pattern.

So far as the human line can be traced back and checked by real specimens from the *Pithecanthropus-Sinanthropus* phase to modern man, evolution proceeds continuously; there are neither leaps nor any indication of chance variations—if chance variations mean the emergence of types or individual features which clearly deviate from the general trend. As in the principle illustrated above, if we test the evolutionary way of man with regard to the way in which it fits into the conception of the origin of species we can only say that the changes to which he was submitted are those of a "macroevolutionary" order although the hominids represent, always, but one species while the single steps appear under the form of "microevolutionary" variations. Schindewolf (1936) doubts that "missing links" ever existed and believes that the first bird hatched from a reptilian egg. In the case of human evolution, we do not know where the first hominid came from but, judging from later steps, it seems certain that *Homo sapiens* was not born one day by a *Pithecanthropus* mother, for all essential intermediate stages are palaeontological records. It is true that E. Dubois (1938) persisted in a belief of stages attained by leaps. He considered *Pithecanthropus* (Trinil Skull) as a "giant gibbon" and supposed that this giant gibbon was directly transmuted into a hominid without even passing through an anthropoid stage. He clung to this idea even after *Sinanthropus* and more complete specimens of *Pithecanthropus* had been discovered, although these specimens proved incontestably the hominid character of the Trinil fragment. Indeed, it was this very evidence which was Dubois' reason for a continued refusal to acknowledge the new finds as true *Pithecanthropus* forms.

F. *Sinanthropus, Pithecanthropus* and Their Supposed Simian Ancestry

In the preceding paragraphs we have discussed the question: in which direction did *Sinanthropus* and *Pithecanthropus* develop. The question which remains is: where did these hominid forms come from. This is a more difficult discussion than that of the first question. For, in the first discussion, starting point, intermediate phases and the goal are known. In the second,

all the links are missing so that we are entirely dependent upon conclusions drawn from living or fossil forms whose relation to the hominids is questioned.

The result of the analysis of man's zoological character, first undertaken by Thomas Huxley (1864) and recently tested by Le Gros Clark (1934) still stands firm: the organization of the human body, whether studied as a whole or in detail, is that of an anthropoid. No fact has become known which has the power to shake this statement. *Tarsiidae* which some considered closer relatives of man than the anthropoids are an early side-branch while the main stem led to the anthropoids, as Le Gros Clark convincingly proved (1934). The palaeontological facts offered by *Sinanthropus* and *Pithecanthropus* confirm, beyond doubt, the close relationship between anthropoids and hominids. Most of the features which prove the primitiveness of *Pithecanthropus* and *Sinanthropus* are anthropoid in their general character. It does not seem necessary to dwell on this point.

Huxley and G. Schwalbe considered chimpanzee as the nearest living relative of man, and orang-utang as the most remote one. More recently Weinert (1931/32) claimed closer relationship between man and chimpanzee by counting the non-adaptive characters and comparing them with those obtained from an analysis of gorilla and orang-utang. From these figures Weinert concluded that orang-utang is the most remote relative and chimpanzee the closest while gorilla is considered as a side-branch of the main stem which leads only to chimpanzee and man. The author stressed this conception by proposing to divide the anthropoids into an Asiatic and an African stock and to unite the latter forms as a special group "Summoprimates" which embraces gorilla, chimpanzee and man. The essential point of this classification is the idea that orang-utang, gorilla and chimpanzee are successive side-branches of the same stem which ends with man. Weinert based his hypothesis chiefly on the comparison of living forms. But even on that evidence his deductions are not tenable. A. H. Schultz (1936) showed that in 23 out of 57 characters considered man resembles the gorilla; in 15 other characters man is nearer to the gibbons and monkeys while in only the 19 remaining characters does man most closely resemble the chimpanzee or—the orang-utang. The order in which the higher primates must be arranged according to their general resemblance is man—gorilla—chimpanzee—orang-utang. Previously Keith (1910/11) had given a similar list. According to that author: 112 characters are common to man, gorilla, chimpanzee and orang-utang; 93 characters are common to man, gorilla and chimpanzee; 98 characters to man and chimpanzee; 87 characters to man and gorilla, and finally 56 characters are common to man and orang-utang. If man could have derived from a common man-chimpanzee stem or a common man-chimpanzee-gorilla stem, as Weinert claims, one would expect the primitive features displayed by *Pithecanthropus* and *Sinanthropus* to reveal a much closer approach to chimpanzee or gorilla than to orang-utang. But before we enter upon a discussion of this question, the general relationship of the hominids to the anthropoids as represented by the living genera must be tested on the data furnished by *Pithecanthropus* and *Sinanthropus*.

I must first restate the fact which I first mentioned in my paper on the limb-bones of *Sinanthropus* (1941a) that the general form and the special features of the femur as well as of the humerus are more like those of modern man than like any of the great apes. The femur of the orang-utang is the most unlike so far as the configuration of its proximal end is concerned, but the one having the closest resemblance when the internal structure of the bone is taken into account. For *Sinanthropus* possesses very thick walls in the shaft of both femur and humerus in contrast to those of modern man, gorilla and chimpanzee, but like orang-utang which shows

similar conditions. Also the proportions of the *Sinanthropus* humerus and femur are clearly of human character as are the lengths of the bones. The humero-femoral index amounts to 79.3 while its average is 73.4 in modern man as against 117 in gorilla, 101 in chimpanzee and 136 in orang-utang. Unfortunately, it is doubtful if the *Pithecanthropus* (Trinil) femur is an authentic *Pithecanthropus* femur but should it prove to be one, its index would shift the figures still more to the human side. It may be argued that the characters of the limb-bones are "adaptive" and as such useless in arguing the question of relationship. But a distinction between "adaptive" and non-adaptive characters is senseless; no one can make such a decision about the characters of the skeleton. I know of no bone, including those of the crania, the form of which could not be interpreted as adapted to special conditions or special functions. In any case, the human form and proportions of the *Sinanthropus* femur suggest that this hominid had already adopted an erect posture, although the skull had not yet reached a correspondingly advanced stage. It is true that so far no limb-bone of a fossil anthropoid has been discovered. But it can be taken for granted that the limb-bones of *Mesopithecus* of the Lower Pliocene of France, those of *Cercopithecus* and *Macacus* of the Lower or Middle Pleistocene of Choukoutien do not differ from those of the living genera. The femur of *Paidopithex rhenanus* of the Lower Pliocene is a typical gibbon femur, although much larger and heavier than the femur of any living form. Taking these facts into consideration, it appears that the limb-bones of the anthropoids had attained their special form and proportions at a very early period, and that, therefore, an early separation of the hominids and anthropoids proper must have taken place.

What we know of the dentition points in the same direction (cf. Weidenreich, 1937b). Of the general character of the *Sinanthropus* teeth I worte: "The *Sinanthropus* teeth as a whole resemble those of lower and primitive, extinct or recent primates only as far as the rather general characteristics of primate teeth are concerned. But in all special features such as the differentiations of wrinkles, size, number and arrangement of the cusps, the feature of the roots and their branches, the *Sinanthropus* teeth conform in principle to those of the anthropoids and differ, together with the latter group, from the teeth of the other primate groups. When applying the teeth as a criterion for classification there is no other choice but to range *Sinanthropus* within the general group of anthropoids." And I continued: "The only difference of some importance is the special form of the canines and the first lower premolar. Although the canine of *Sinanthropus* has already undergone a reduction, it cannot be surmised that it had at any time such a tusk-like structure as is true in anthropoids; the premolar likewise probably never had such a sectorial character as that found in anthropoids. These teeth apparently were the center of special differentiations in anthropoids which already were effective in *Dryopithecus*." The first statement on the general character of the hominid tooth obtained by the study of the most primitive hominid dentition, so far known, is in complete conformity with the earlier one of Gregory and Hellman (1926). These authors compared the teeth of Neanderthal and modern man with those of *Dryopithecus* and arrived at the conclusion that man and anthropoids belong to the same group because of their agreement in principal tooth patterns. Le Gros Clark wrote, in 1934: "That man has been derived from a form which—without imposing any strain on commonly recognized definitions—can be properly called an "anthropoid ape" is a statement which no longer admits of doubt." Yet, in 1940(a), this author criticized my statement on the *Sinanthropus* dentition, which I quoted above, in the following words: "In spite of certain simian features such as are presented by the large size of the teeth, the characters of the lower premolars and some details of the molar cusp pattern, this statement can only be regarded as an unfor-

tunate and misleading hyperbole." I wonder why it is a "misleading hyperbole" when I speak of *Sinanthropus* as belonging to the "general group of anthropoids" but not a hyperbole when Le Gros Clark himself calls even *Homo sapiens* an "anthropoid ape."

In the second of my statements which I cited above I emphasized the differences between the hominid and the anthropoid dentition which are so fundamental that they demand a separation between hominids and anthropoids proper. I designated the first branch as the "homomorphic canine group" and the second as the "heteromorphic canine group." By "heteromorphic canine group" is meant the group characterized by a tusk-like canine together with a sectorial pattern of the first lower premolar—the characteristic of the living anthropoids. By "homomorphic canine group" is meant the group with relatively small canine together with a typical bicuspidate first lower premolar—the characteristic of modern man. In the latter group the lower canine originally appeared more like an incisor than like a canine, as the *Sinanthropus* dentition revealed. The contrast which exists between the upper and lower canines can be gathered from Figure 274 A and B. In addition, Figure 275 shows a first lower premolar of *Sinanthropus* with a very well developed lingual cusp which certainly differs considerably from the sectorial type of the anthropoid premolar. As to the dentition of *Pithecanthropus*, neither the lower canine nor the first lower premolar is preserved but the size and form of their sockets indicate that they did not differ from the *Sinanthropus* teeth: in other words, *Pithecanthropus* is also characterized by a "homomorphic canine group."

The differences between the two canine groups seems closely related to differences in the length of the jaws. In comparison with the three living anthropoids, *Sinanthropus* and *Pithecanthropus* have much shorter jaws. The maxilloalveolar index of the average gorilla is 64.7 for males and 72.5 for females. The corresponding figures for orang-utang are 74.8 and 81.9; those of chimpanzee 80.8 and 82.0, respectively. The maxilloalveolar index of *Sinanthropus* is 107.6 while the average of modern man is 117.5. The length-breadth index of the alveolar arch of the mandible, corresponding to the maxilloalveolar index totals 61.6 in female gorilla, 65.4 in female orang-utang and 69.0 in male chimpanzee as against 100.8 in *Sinanthropus* and 126.0 in modern man. Compared with anthropoids the hominid maxilla and mandible are much shorter and wider or, conversely, the jaws of anthropoids are longer and narrower.

In a previous paper on the development of the human chin (1934) I was able to show that the changes undergone by the human mandible when passing from the infantile stage to that of the adult differ in principle from those the anthropoids experience within the same period. If the dental arch is divided by a transverse line which connects the "postlactea" of both sides—"postlacteon" (according to Bolk, 1924) is a landmark situated between the second deciduous molar or second premolar and the first permanent molar, or between the deciduous and permanent dentition—, the length and width of the anterior or "lacteal" portion of the dental arch can be measured in infantile and adult mandibles. In modern man the arch increases in width and decreases in length, as shown in Figures 276 and 277. This fact is also proved by the following figures. The width of the "lacteal" arch amounts to 36 mm. in the average European and the length to 21.5 mm. The same dimensions of the "permanent" arch are 39 and 18.5 mm., respectively. The increase in width is 3 mm. or 8.5 per cent; the decrease in length is also 3 mm. or 14.0 per cent. In the case of the South American Indian depicted in Figures 276 and 277, the figures for the width are 36 mm. and 43 mm., respectively, and those of the length are 24 mm. and 18 mm. The increase in width is 20 per cent and the decrease in length is 25 per cent. The lacteal arch is longer than the permanent one because the space occupied by the deciduous denti-

tion is larger than that of the permanent. This is particularly true of the deciduous molars and the two premolars which take their places. The first permanent molar which marks the end of the deciduous dentition keeps its place in both dentitions.

In all anthropoids the conditions are different especially in the male individuals. Figures 278 and 279 demonstrate how enormously the lacteal arch has been prolonged, apparently because the permanent incisors, canines and premolars are much bigger than the corresponding teeth of the deciduous dentition which they replace. In this case the increase of the lacteal arch in length is 14 mm. or 49 per cent. In the female chimpanzee the increase is much less, amounting only to 13 per cent. In male baboons, on the other hand, the prolongation considerably exceeds that of the anthropoids reaching to over 100 per cent. *Sinanthropus* follows the human line as Figure 280 shows. The lacteal arch is considerably longer in Sinanthropus child B IV with complete deciduous dentition than in the female adult Mandible H I. There is, therefore, no approach to the anthropoid pattern though crown and roots of the *Sinanthropus* teeth are considerably bigger than those of modern man.

All this indicates that the shortness of the hominid muzzle together with the homomorphic character of the canine group is a genuine hominid peculiarity and is, therefore, to be considered as a specific difference between hominids and anthropoids proper.

The calvaria shows additional features of the same kind. One of the most conspicuous is the position of the occipital foramen. In all the anthropoids the foramen is placed near the posterior end of the base; in man it occupies a rather central position. One would expect, therefore, that in *Sinanthropus* and *Pithecanthropus* the foramen would lie closer to the posterior end of the base than it does in modern man. But this is not the case. The figures obtained by all possible measurements lend no definite support that the foramen occupies a more backward position in *Sinanthropus;* in *Pithecanthropus* Skull IV it undoubtedly holds a central one. A. H. Schultz in a recent study (1942) examined the conditions among primates involved in balancing the head and found that very much less strength is required to balance the head of an adult man than of adult anthropoids. In proportion to the total head-weight the weight necessary to balance the head at inion is 22.3 per cent in adult man while it is 120.0 in adult apes. Fossil man—Schultz experimented with the casts of Gibraltar and Rhodesian man—does not bridge the large gap between great apes and modern man as regards the particular factors involved in balancing the head, says this author. The head is balanced on the condyles but the position of the condyles in relation to the occipital foramen is the same in hominids and anthropoids: in each case a transverse line tangent to the anterior ends of the condyles passes just in front of the basion. The facts found by Schultz, therefore, prove that, in the balance of their heads, the Neanderthalians also behave as does modern man and do not approach conditions of the anthropoids.

That the massiveness of the cranial bones and their special reinforcement-system must be considered a peculiarity of primitive hominids without parallel in anthropoids, has already been discussed. The reinforcement-system of the anthropoids is limited to the frontal torus and the lateral part of the basic ring. But there is no sign of a sagittal crest and an occipital torus continuing forward to the mastoid portion; both are replaced in the apes by structures of purely musculo-facial character. The Sylvian crest of primitive hominids which represents a very characteristic piece of the basic framework is absent in the great apes except the orang-utang where it is slightly indicated, for the massiveness of those cranial bones which have special connection with the air-passages has been replaced in anthropoids by vast air-sinuses. These are

not wanting in hominids but never reach a similar state of expansion. The special tendency, in anthropoids, to expand their air-cells into single vast spaces so that, for instance, the sphenoidal sinus or the ethmoidal cells appear as mere appendices of the maxillary or frontal sinus, has never taken place in hominids.

To these general peculiarities which distinguish hominids from anthropoids, others of more special character may be added. They may be found in gorilla, in chimpanzee or in orang-utang; or they may be found in two of the types and not in a third or in all three. In my previous paper (1936b) I showed that in the *Sinanthropus* mandible the characteristic parallelism between alveolar and basal plane and steepness of the rami resembles more nearly the conditions found in gorilla and orang-utang than those found in chimpanzee. The flatness of the lingual surface of the frontal part is more like the condition in orang-utang than those of gorilla or chimpanzee. The position of the digastric fossa is the same as that in chimpanzee and gorilla. The development of the muscle markings for the attachment of the pterygoidei is similarly pronounced in gorilla.

The crown patterns of the *Sinanthropus* and *Pithecanthropus* teeth, when considered as a whole, show a definitely anthropoid pattern yet they conform to no pattern of any living ape. When the occlusal surface of the lower molars is taken as an example the cusps are much higher and more distinct than in orang-utang, but lower and less pointed than in gorilla and chimpanzee. The wrinkles are less abundant than in orang-utang but more so than in gorilla and chimpanzee. Although the pattern of the chimpanzee molars is the most similar, there is an essential difference between *Sinanthropus* and chimpanzee dentition. The crowns of the upper and lower incisors of the chimpanzee are very large in proportion to those of the corresponding molars while they are very small in hominids.

TABLE XXXVIII

Index of Robustness of the Crowns of the Medial Incisors in Proportion to the First Molars in Sinanthropus and Anthropoids

	Med. Incisors		First Molars		Indices	
	Upper	Lower	Upper	Lower	Upper	Lower
Sinanthropus ♂ + ♀	80	44	146	150	54.7	29.4
Chimpanzee ♀	114	77	112	94	101.9	81.0
Gorilla ♀	119	55	224	207	52.2	26.6
Orang-utang ♀	95	80	150	147	63.3	54.5

* The figures are taken from the "*Sinanthropus* dentition" (Weidenreich, 1937b).

When the ratio between the size of the medial incisors and the first molars is expressed by indices (see Table XXXVIII) the index of the upper medial incisors of *Sinanthropus* is 54.7 as against 101.9 in the female chimpanzee. The lower incisor index is 29.4 as against 81.0 of the chimpanzee. In other words, the crown of the upper incisor of the chimpanzee is about twice as big as that of *Sinanthropus* and the crown of the lower incisor almost three times as big. This disproportion in the chimpanzee dentition has nothing to do with the general size of the teeth, for the first molars of the chimpanzee are much smaller than those of *Sinanthropus* (see Table XXXVIII); the upper molar of the former reaches only 77 per cent of the size of the latter and the lower molar only 63 per cent. Gorilla, despite the size of its teeth being double those

of the chimpanzee (see Table XXXVIII), shows the same ratio between incisors and molars as does *Sinanthropus*. Orang-utang takes a more intermediate position between chimpanzee and gorilla. From all of which we may conclude that, in this respect, chimpanzee is further from *Sinanthropus* than either gorilla or orang-utang.

As to the non-metrical features of the cranial bones: The frontal torus of *Sinanthropus* resembles that of gorilla and chimpanzee, but in orang-utang the supraorbitals form a half-ring set in the supraorbital margin while a glabellar torus has not developed. The supraorbital notch and the supraorbital process are lacking in all three apes but are very distinct in macaques and baboons. In *Sinanthropus* the nuchal plane is rather flat as a whole and the lower occipital scale forms a distinct angle with the upper one. In the anthropoids there is no angle between the two scales, if the crest is disregarded, while the entire occipital squama appears as a continuous curve. The most characteristic differences are presented by the temporal bone. The triangular form of the squama is found in all three anthropoids but the parietal notch is only constant in orang-utang. In all three anthropoids the articular tubercle is lacking and the mandibular fossa very shallow, if existing at all. Furthermore all have well-developed postglenoidal and entoglenoidal processes. No essential differences are recognizable in the configuration of the tympanic plate and the base of the pyramid. The tympanic plate extends furthest in a lateral direction in gorilla and least in chimpanzee. They styloid process is completely absent in chimpanzee while it is sometimes represented by a short piece of bone in gorilla and orang-utang. The mastoid process and the incisura mastoidea is very indistinct in chimpanzee and orang-utang but well developed in gorilla, both in males and females.

All three anthropoids agree in possessing a very flat nasal bridge, a pronounced frontal orientation of the entire cheek region and an enormous projection of the maxilla. Although these peculiarities are less pronounced in chimpanzee than they are in gorilla and orang-utang, they far exceed the same conditions in primitive hominids. Two special features present in *Sinanthropus* are of some interest because both occur in orang-utang, are much less pronounced in chimpanzee, but are absent in gorilla. One feature is the malar notch—incisura malaris. The other is the "processus marginalis" of the fronto-zygomatic process of the os zygomaticum—or more correctly the incisura frontozygomatica and the incisura zygomaticotemporalis. Both peculiarities seem not to be specific of hominids, because they are never found in the Neanderthalians. But it is certainly interesting that they are rather pronounced in *Sinanthropus* and developed to the same extent in orang-utang.

Those coincidences cannot be interpreted as indications of a closer relationship between *Sinanthropus* and orang-utang in Klaatsch's sense (1910), certainly not more than those between man and chimpanzee in Weinert's sense (1931/32). The only possible conclusions to be drawn from the recorded facts support the view of A. H. Schultz, namely, that the three living great apes form one group and the hominids another. The characters in which the three apes agree and in which they differ from the hominids are not only more numerous but also more important, from the viewpoint of their organization, than those common to man and any member of the anthropoid group. This holds good not only for living man but for *Sinanthropus* and *Pithecanthropus* also.

The main hominid characters are clearly discernable in the early human stage of evolution. Unfortunately, all the fossil anthropoid material now at hand consists only of jaws and teeth—if *Australopithecus* and kindred types are disregarded for the moment. Comparison with *Dryopithecus* and *Sivapithecus* which are regarded as ancestors of the recent anthropoids shows that

their dentition already displays the principal character of modern forms; namely, a heteromorphic lower canine group with a big, pointed canine and a typical sectorial first premolar. The symphyseal section of the mandible is long and narrow and the inner side of the mental area reveals the usual anthropoid pattern (cf. Gregory and Hellman, 1926). *Sivapithecus* differs from *Dryopithecus* in having a shorter symphysis (Pilgrim, 1927), but the shortening is not comparable to that of the hominids.

These facts certainly suggest that the separation between anthropoids and hominids took place at an early anthropoid stage—or more precisely, the supposed primitive stem from which both anthropoids and hominids have derived must have split into two final branches, one of which embraced the anthropoids proper, the other the hominids. This must have happened before the differentiation of *Dryopithecus* and related forms took place. Gregory and Hellman (1926), however, not only consider *Dryopithecus* as ancestral to the recent anthropoids but to the hominids as well. In this case the homomorphic lower canine group of hominids would not represent the primary condition but a secondary one. Teeth like the human canine and first premolar would have derived from those specialized ones characteristic of *Dryopithecus* and *Sivapithecus*. This problem is not a mere controversy upon tooth patterns. If *Dryopithecus* should be the direct ancestor of the hominids, the latter may have developed lately—perhaps not earlier than Lower Pliocene. However, should *Dryopithecus* represent a side-branch, already specialized and deviated from the main anthropoid stem after having given rise to the hominids, the separation would have to be dated further back—at least in the Lower Miocene.

It is regrettable that in order to reach such a decision we must depend solely on teeth and the interpretation of tooth-patterns. Cranial and limb bones would be of much greater service. But there are other factors which may point the direction in which the solution is to be sought. As already mentioned, judged from the gibbon of today, the femur of *Paidopithex rhenanus* was already specialized in the Lower Pliocene and macaque and *Ceropithecus* were specialized in the Lower Pleistocene at the very latest. The fossil orang-utang which lived contemporaneously with *Sinanthropus* and *Pithecanthropus* had teeth not substantially different from those of the modern orang-utang (cf. Weidenreich, 1936b). New light has also been shed on the whole subject by the fairly recent discovery of *Australopithecinae* of South Africa. It is not my intention to discuss all the facts known about this strange anthropoid group at this point. In my paper on the *Sinanthropus* dentition (1936b) I dealt with the tooth-pattern of *Australopithecus africanus* Dart, the only genus known at that time. My verdict about the position of that group within the primate order reads as follows: "Of all fossil anthropoid-like primates known hitherto, *Australopithecus* bears the closest resemblance to *Sinanthropus* with regard to the dentition. This is true not only of the first permanent molars but also of the deciduous molars and the proportion of the size of the incisors in proportion to that of the molars. The lack of a diastema and the remarkable smallness of the canine in Broom's *Australopithecus* point in the same direction. Therefore, *Australopithecus* apparently belongs to the same anthropoid main branch as the hominids which are characterized by greater homogeneity of the canine group."

The two new genera recorded in the meantime and designated by Broom (1938b; 1939b) *Plesianthropus transvaalensis* and *Paranthropus robustus* show the same characteristics as *Australopithecus*, although they differ from the latter and from one another in details. Their conformity to *Australopithecus* is all the more important since they represent adult individuals with permanent dentition, whereas Dart's *Australopithecus* possesses only the deciduous teeth beside the permanent first molars. Both *Plesianthropus* and *Paranthropus* have relatively

small upper and lower canines, a non-sectorial first premolar, no diastemata in upper and lower jaws, small incisors but large molars. *Plesianthropus*, first discovered and called by Broom (1938a) *Australopithecus transvaalensis*, is probably a female and has a very small canine. The tooth is worn but the crown was certainly not higher than that of *Sinanthropus* or *Pithecanthropus* Skull IV. The pattern, so far as it is possible to see it, comes very close to that of the *Sinanthropus* canine. Gregory and Hellman (1939a and b) say: "With regard to the general morphology, this female upper canine of *Plesianthropus* is unlike the high-crowned tusks of either male or female recent apes. Its partly worn tip has evidently been fairly blunt, and the crown as a whole approaches certain human canines more nearly than it does those of typical modern apes." A well preserved lower canine found at the same locality has been attributed by Broom to a male *Plesianthropus* because its size considerably exceeds that of the earlier known upper canine belonging to a female. In Figure 281 this *Plesianthropus* tooth (A) is placed beside the right lower canine of a fossil female orang-utang (B) found in a cave in Yunnan (South China). This orangutang tooth was depicted in my paper on the *Sinanthropus* dentition (1937b, Pl. VII, Fig. 61), but to facilitate the comparison here the tooth has been reversed and the left side shown. Contrary to the upper canine of *Plesianthropus*, its lower canine comes very close to the orang-utang tooth. The differences, apart from size, are the development of a more incisor-like edge on the medial moiety of the tooth instead of the bevelled edge of the distal moiety. In *Sinanthropus* the lower canine has the appearance of an incisor while the upper one resembles the anthropoid tooth to a greater degree. The first lower premolar is not preserved in *Plesianthropus* but in *Paranthropus robustus*. According to Gregory and Hellman (1939a) the crown, as a whole, is more like that of the associated second premolar than like that of the compressed first premolar of the *Dryopithecus* stock; "in fact this crown, as well as that of P_2, is essentially like that of *Sinanthropus*." In other words, the first lower premolar of *Paranthropus* has not a sectorial but a bicuspid pattern like the hominids.

A diastema is missing in the upper and lower jaws of *Plesianthropus* and *Paranthropus*. In this respect both anthropoids agree with *Sinanthropus* but not with *Pithecanthropus*, at least so far as the upper dentition is concerned, for *Pithecanthropus* Skull IV exhibits a distinct diastema between lateral incisor and canine (Fig. 248; and Weidenreich, 1940a) while there is no diastema in the *Pithecanthropus* Mandible B. As I set forth in my paper on the *Sinanthropus* dentition (1937b), the formation of a diastema has nothing to do with the size of the canines. The mandibular diastema is of quite a different kind from the maxillary diastema. The former is not a true interstice between the roots or sockets of canine and premolar; the impression of a gap is produced by the distance between the tip of the premolar and the erected crown of the canine. If there is a wide distance, it is because the crown of the premolar recedes and its anterior root extends forward in order to form a long cutting blade for the overlapping upper canine. If, therefore, the premolar is not a sectorial type but a bicuspidate tooth, a diastema is completely lacking. On the other hand, the maxilla diastema is located at the boundary between premaxilla and maxilla, and the gap is caused by the change in the direction of the incisors and the upper canine. For this reason the diastema is the wider the more the incisors are procumbent and the canines vertical. The size of the lower canine has no bearing upon the development or the width of the maxillary diastema as is proved by the conditions in the lower primates. The disappearance of the diastema, therefore, is not related to the reduction of the canines, as Ashley Montagu has recently (1940) supposed. More decisive is the fact noted by the same author that "the maxillar incisor teeth (of *Homo sapiens*) are no longer markedly procumbent but are more or less vertically

oriented." *Pithecanthropus* has no mandibular diastema because his first premolar is of a non-sectorial type; yet he shows a pronounced maxillary diastema despite his possession of a small canine, for the sockets of the incisors (preserved in Skull IV) are oriented in a forward direction while the canine is implanted vertically.

The last peculiarity characteristic of the *Plesianthropus* and *Paranthropus* dentition is the small size of the upper and lower incisors in proportion to the molars. This disproportion is stressed by Broom as well as by Gregory and Hellman. The molars are very big: the "robustness" (length times breadth which is called "molar rectangles" by Gregory and Hellman, 1939a) of the first upper molar amounts to 154 in *Plesianthropus* and to 177 in *Paranthropus*. The corresponding figure of the lower molar is 181 in *Paranthropus* but cannot be ascertained in *Plesianthropus* since that tooth is not preserved. If the contour of the socket, given by Broom (1939b), is considered sufficiently reliable for use in this measurement, the robustness is 156. The medial incisors which are used for comparison (cf. Table XXXVIII) are not preserved in either of these anthropoids. The robustness of the medial upper incisor of *Plesianthropus* totals about 64 (calculated on Broom's contours of the socket) and about 34 (according to the same source) for the lower tooth. The corresponding figures of *Paranthropus* are about 81 for the upper incisor and about 21 for the lower one. The indices calculated from these measurements are 41.5 and 45.6 for the upper dentition of *Plesianthropus* and *Paranthropus*, respectively, and those for the lower dentition 22.4 and 11.6. In other words, the incisors of *Plesianthropus* and *Paranthropus* are smaller in proportion to the size of the molars than those of any of the living anthropoids or hominids. As comparison with the figures given in Table XXXVIII shows, their incisors are much smaller even than those of gorilla, leaving orang-utang and, particularly, chimpanzee quite aside.

The relationship between the hominids and the *Australopithecinae* can only be discussed when the relationship between the latter and the anthropoids is known. There seems to be a general agreement among all the students that the *Australopithecinae* represent a true anthropoid group in spite of the fact that they have some features in common with the hominids. Only von Koenigswald (1942) goes so far as to deduce from their dentition that "they cannot be excluded from the hominids using the word in a broad sense." I think we should attempt to make as definite a classification as possible. Therefore, in assigning a definite position to the *Australopithecinae* we cannot depend upon the dentition alone; other structural peculiarities have to be taken into account. But if we do this, little doubt remains that the skulls of *Australopithecus africanus* and *Paranthropus robustus* are the skulls of apes and not of hominids. Even if we admit that the cranial capacity of the adult *Australopithecus* may have amounted to 600 cc. (Keith, 1931), the capacity remains within the range of the gorilla variations and is still far below that of *Pithecanthropus-Sinanthropus* and the same is true of the capacity of *Plesianthropus* estimated by Broom (1938b) as 450 to 600 cc. Regarding the skull of *Paranthropus robustus*, the small occipital condyle, the posterior position of the occipital foramen, the inflated mastoid portion, the pronounced maxillary prognathism and the form of the dental arch are certainly not human. To this must be added the fact that the characters of the cusps and the wrinkles of the lower molars are much more like those of the gorilla than those of the hominids. Broom deduces from the position of the occipital condyle in relation to the auditory meatus that *Paranthropus* had already adopted an erect posture. In one of the preceding paragraphs dealing with the position of the occipital foramen, I have already given my reasons for being skeptical of those conclusions. In any case, the occipital foramen lies in *Paranthropus* much farther back than in any hominids

in all of which it occupies a fairly central position. Regarding the distal ends of the humerus and femur attributed by Broom (1938c) to *Paranthropus* and *Plesianthropus*, respectively, further evidence must be offered before a verdict can be given. As far as the drawings permit of judgment, the bones appear of so human a nature that their attribution to anthropoid forms seems doubtful. The sections through the mandibular symphysis of *Paranthropus* and *Plesianthropus* given by Broom (1938c) reveal an undoubtedly anthropoid character.

On the other hand the *Paranthropus* skull (cf. Broom 1938b, Fig. 2) shows, beside the dentition, some features which are astonishingly human. This holds particularly true for the mandibular fossa and the structures surrounding it. There is a well-developed articular tubercle and a wide and deep fossa; the entoglenoid process is a low elevation; the postglenoid process is also a low ridge which separates the tegmen pori acustici from the fossa; the posterior wall of the mandibular fossa is formed by the tympanic plate itself which has assumed a rather vertical position; the tympanic crest does not run in a transverse but in an oblique direction. Unfortunately, the pyramid in the only available specimen is so crushed that no details are recognizable. But there can be no doubt that those peculiarities which I have enumerated are scarcely distinguishable from those found in *Sinanthropus* (see the description of the temporal bone above) and are quite different from the corresponding features of all three anthropoids.

The mandible of *Paranthropus* (cf. Broom, 1938b; Fig. 3) also shows some peculiarities which are absent in the great apes but which occur in hominids. Of all of these, the thickness of the bone is especially characteristic. Since the entire base is broken off except for a small portion of the ramus region, the index of robustness of the body can only be estimated. It amounts to more than 80. The thickest human mandible known so far (cf. Weidenreich, 1936b) is the mandible of Malarnaud with an index of 60.4; then follows La Naulette with 57.7 and Heidelberg with 52.9. Orang-utang and gorilla have an index of not more than about 50 and chimpanzee has no more than 60. It is true that the average index of the *Sinanthropus* mandible is only 56 and that of *Pithecanthropus* is even below 45 but, as shown in my paper on the *Sinanthropus* mandible, the index alone does not give a correct idea of the proportion. It must be completed by a statement of the height and thickness. The height of the *Paranthropus* mandible, measured at the level of the mental foramen, amounts to about 31 mm. and the thickness at the same level to 25.5 mm. The *Paranthropus* mandible is 10 mm. thicker than the *Sinanthropus* and *Pithecanthropus* mandibles. It has about the same thickness as the jaw of a big male gorilla while it is much lower—31 as against 44 mm. This extraordinary massiveness of the *Paranthropus* mandible recalls the conditions of the giant mandible of Java which was recently discovered and to which I alluded above. This Java mandible is undoubtedly hominid but its thickness reaches 27.7 mm. at the level of the mental foramen. The second feature in which the *Paranthropus* mandible agrees with those of *Sinanthropus* and *Pithecanthropus* is that the mental foramen divides into three or even four orifices which agree in size and arrangement with those of the primitive hominids.

Taking all these facts into account, *Paranthropus*, *Plesianthropus* and *Australopithecus* have to be considered as primates which combine a basic anthropoid character with some fundamentally hominid features. Broom (1939b) regards the *Australopithecinae* extinct primate forms but as a late survivor of an allied Pliocene type from which man "might have arisen by a fairly rapid increase in brain development." According to Gregory and Hellman (1939a) "the *Australopithecinae* have such a mixture of characters because they were late Pleistocene survivors of the common *Dryopithecus* stock, and were truly related to all their cousins of the modern

chimpanzee, gorilla, orang-utang and human branches." Šenyürek (1941) assumes that "after the separation of the last true anthropoids from the common anthropoid stem the *Australo-pithecinae* continued as a common stock with the later hominids for some time." The latest author to advance an opinion on the relationship between the *Australopithecinae* and man is von Koenigswald (1942). He attributes the *Australopithecinae* to the *Hominidae* "in a broad sense" but, for the rest, confines himself to the statement that they cannot be ancestral to man because they are geologically too young and their molars are too large.

In my paper on the *Sinanthropus* dentition (1936b), written when only the *Australopithecus* child was known, I placed the *Australopithecinae* together with the hominids in the same anthropoid main branch but separated them from the anthropoids proper which led, as I believe, from *Dryopithecus* and kindred forms to only the orang-utang, chimpanzee and gorilla of today. The more recent discoveries of *Plesianthropus* and *Paranthropus* make it possible now to venture a more precise suggestion as to these relations. In the matter of relationship between *Australo-pithecus africanus* Dart, *Plesianthropus transvaalensis* Broom and *Paranthropus robustus* Broom, I believe that the first of the three comes closer to man than the two remaining; this conclusion is based exclusively on the different character of the pattern of the first permanent molar. The *Australopithecus* pattern is very similar to that of *Sinanthropus* while the *Paranthropus* pattern looks more like that of gorilla. In his most recent paper on the milk molars of man and anthropoids Broom (1941) arrived at the conclusion that *Australopithecus* cannot be nearly related to the gorilla and chimpanzee but must be related to man. He finds that "the first upper and lower milk molar in man and *Australopithecus* are very unlike those of the living anthropoids while the second milk molars of both upper and lower jaws agree in the main in all the higher primates." I have already called attention (1936b) to the fact that in *Sinanthropus* as well as in *Australo-pithecus* the trigonid is almost completely preserved in the first lower milk molar, whereas it is lost in recent anthropoids (cf. 1936b; Pl. 21, Figs. 194–201). In the second lower milk molar the trigonid is also retained in *Sinanthropus* and looks very like that of the permanent molars of Eocene Tarsoids. The *Sinanthropus* molar, I stated in my paper, is "at least as primitive as that of the stronger worn *Dryopithecus* milk molar (cf. Gregory 1922; Fig. 287, p. 380, and Weidenreich, 1936b; Pl. 36, Figs. 343 and 344), and certainly much more primitive than that of the chimpanzee." The *Australopithecus* molar resembles that of *Sinanthropus* much more than that of a gorilla (cf. 1936b; Pl. 21, Figs. 200 and 201).

Despite the differences which apparently exist between the three known representatives of the *Australopithecinae*, they can safely be regarded as a special group when contrasted with the anthropoids proper, on the one hand, and with the hominids, on the other. In order to assign *Australopithecinae* and hominids to their proper places it must be borne in mind that the first two groups have a number of distinct features in common which are not found in anthropoids. The question then arises as to whether these common features are primitive ones which have been lost by the anthropoids or whether they must be counted as late acquisitions made by the *Australopithecinae* but not by the anthropoids. If we begin with the dentition, are the shortness of the muzzle and the homomorphy of the canine group primary characters and the elongation of the muzzle and the heteromorphy of the canine group secondary characters? Or are the conditions of these reversed? If *Dryopithecus* is considered the ancestor of hominids as well as anthropoids, anthropoid conditions would be primary and those of hominid secondary. In this case the *Australopithecinae* must have been transformed in the same direction as the hominids.

In Figures 276–280 I have shown that the elongation of the anthropoid muzzle becomes manifest only after the eruption of the first permanent molars, apparently as a consequence of the greater length of the premolars (particularly the first one) which take the place of the much shorter milk molars. The mandible of the mandrill shows that the elongation is indeed the more pronounced, the longer the first premolar is. In the case of the macaques and some of the *Semnopithecinae*, the first premolar is much shorter and, consequently, the lacteal arch. The reasons I consider the hominid dental conditions as primary and the anthropoid conditions as secondary are as follows: (1) The *Sinanthropus* lower canine, in contrast to the upper, has the character of an incisor (Fig. 274 B), a condition lost in the later stages of human evolution. (2) The lower canine of the only known fossil orang-utang (Fig. 281 B) shows much more primitive features than the canine of the living orang-utang, and these primitive features are identical with those of the primitive hominid canine of *Sinanthropus*. The course taken in the transformation of the canine proceeded, therefore, from an incisor-like tooth to a tusk-like one but not in the reverse order. (3) As Remane (1921) showed, there is considerable variation in the form and pattern of the canine among living great apes. In many cases these resemble the original incisor-like form. (4) The first lower premolar of *Sinanthropus* already has two opposing cusps but neither a cutting blade nor is the anterior root directed forward. (5) *Oreopithecus* (Schwalbe, 1915, and Gregory, 1922) has well-developed, bicuspid lower premolars, and *Ramapithecus*, indicatively named by G. E. Lewis (1934) "*brevirostris*", has upper premolars, canine and incisors of an undoubtedly hominid character, while no diastema has developed. (6) The first milk molar of *Sinanthropus* retained the original trigonid which is partly lost in recent anthropoids. In all these features the *Australopithecinae* agree with the hominids and disagree with the anthropoids. In connection with the same line of reasoning the lower canine of *Plesianthropus* is of special interest (Fig. 281 A). It combines an incisor character (mesial moiety) with a tusk character (distal moiety), a combination which becomes still more impressive when the mesial moiety is replaced by the same portion of the *Sinanthropus* canine (Fig. 282), and this artificial combination is compared with the unaltered *Plesianthropus* canine as shown in Figure 281 (A, 1).

That the hominid conditions and those of the *Australopithecinae* are the primary ones can also be deduced from the special conformation of the mandibular fossa. A deep fossa and, therefore, a "tuber articulare" is found in all juvenile anthropoids but the region becomes level during the later ontogenetic development. The massiveness in the hominid skull together with a special reinforcement-system is another proof that this peculiar feature cannot have been acquired after the hominids had branched off from the anthropoid stem, for, had that been the case, there would have been no adequate reason for the disappearance of these structures so shortly after they were acquired. Therefore, as I said above, massiveness is to be regarded as a primitive character which must have been peculiar to the *Australopithecinae* and hominids alike. The massiveness of the *Paranthropus* mandible which caused Broom to give this type the name "robustus" has its parallel in the giant hominid mandible recently discovered in Java and is still recognizable in the Heidelberg jaw. Broom (1939c) put von Koenigswald's *Gigantopithecus* (1935) "somewhere near" what he believes "to be the origin of man and the *Australopithecus* group of anthropoids," because he assumes that "man's foot could only have developed from the foot of a heavily built ape." After an additional lower molar of *Gigantopithecus* had been discovered by von Koenigswald—and this time a well-preserved and scarcely worn tooth— Broom's suggestion is better substantiated. For, on the basis of this new evidence, *Gigantopithecus* is to be considered not only as true anthropoid but as a type very close to the hominids—

if not already as a true hominid. Yet it possessed a mandible the size of which must have far exceeded that of the living male gorilla.

If a form such as that of a living anthropoid or of the extinct *Dryopithecus* which had all the main characteristics of the living form already developed—if such a form had been the ancestor of the hominids and the *Australopithecinae*, than specific hominid-australopithecine characters must have developed afterward. In the *Australopithecinae* only the dentition and certain cranial bones would have been affected while most of the remaining structures would have been untouched and would have preserved their original anthropoid character. On the other hand, there is evidence that the anthropoids *did* undergo a great many differentiations which led them away from the common stem. This holds true, for instance, for the length and proportion of the extremities and their constituent bones; femur, humerus, fingers, toes etc. Why should this not hold good also for the dentition and the other features of the skull?

The original stem which produced the hominids gave origin to the anthropoids proper and also to the *Australopithecinae*. There can be no closer relationship between chimpanzee and hominids or between gorilla and hominids than between orang-utang and hominids. The three anthropoids are, in the phylogenetic sense, equal offspring of the same side branch of the main stem. The fact that hominids have some features in common with chimpanzee, some in common with gorilla and still others in common with orang-utang can be explained in various ways. So far as those features represent true, primitive characters they may have been retained by the anthropoids while others were lost in the course of special differentiation. Features of a more accidental character may be the result of parallelism in evolution. Finally, consideration must be given to the fact that interbreeding might have taken place, not only in the earlier stages of differentiation into branches and types but in the later stages as well. The *Australopithecinae* cannot be widely separated from the forerunners of gorilla—as suggested in the genealogical trees of Broom (1939a) and Senyürek (1941)—, for they have too many features in common. On the other hand, it does not seem possible to separate them entirely from the hominids. They must, therefore, he placed near the point where hominids and anthropoids proper diverged but, apparently, nearer to the gorilla branch than to any other of the three types. We must, furthermore, hold constantly in mind the fact that interbreeding may have given the *Australopithecinae* some of their characteristic stamps.

In the present state of our knowledge, it is impossible to say anything about the appearance of the probable ancestors of the hominids either immediately before or immediately after their separation from the common stem. What can be said is merely that these forms were in all likelihood more nearly similar to *Australopithecinae* types than to living anthropoids or the various *Dryopithecus* forms. At the time they branched off, these ancestors must have already developed human-like proportions of trunk and extremities, a fairly central position of the occipital foramen, a "brevirostral" face with small canines only slightly prominent and a bicuspidate first lower premolar. From such a type *Homo sapiens* has gradually enlarged brain and braincase. The transformation of the skull progressed according to that biological rule which governs the correlation between braincase and face, as set forth in my paper on the brain and its rôle in the phylogenetic transformation of the human skull (1941b).

As regards the geological period in which this event occurred, all the facts at present available indicate that the transformation, so far at least as the later phases are concerned, has been accomplished during the Pleistocene, but the first steps which separated man from the common anthropoid stock must have taken place considerably earlier. If *Dryopithecus* is excluded from

the ancestral line—as I believe it should be—and considered as an anthropoid proper which has already differentiated in the direction of the living forms, then man's roots reach down deeply into the Tertiary, perhaps even into the Lower Miocene. Gregory and Hellman as well as Broom deny such great age to man's evolution. I am unable to see the reason for their objections. It is certain that *Dryopithecus*, an already fully developed anthropoid, lived in the Middle Miocene of Europe and a fully developed giant gibbon (*Paidopithex rhenanus*) lived in the Lower Pliocene of the same continent. Why then, should man, too, not have made his appearance at such an early time? Not, of course, as a fully developed type but only as a barely recognizable hominid.

SUMMARY OF PART III

1. *Sinanthropus* and *Pithecanthropus* are the most primitive hominids so far known. Of the 121 main characters of the *Sinanthropus* skull—excluding mandible and dentition—, listed in the Analytic Summary of Part II, 74 can be checked in *Pithecanthropus* while the remaining 47 are parts not preserved in *Pithecanthropus*. In 57 out of these 74 main characters *Sinanthropus* and *Pithecanthropus* completely agree. Eight characters are doubtful and five accidental ones. So that *Pithecanthropus* and *Sinanthropus* differ in but four characters.

Hrdlička's view, according to which *Sinanthropus* may not even represent the lowest type of the Neanderthalians but rather correspond to such an advanced type as that of the Galilee skull, is without any foundation.

2. "*Eoanthropus*" should be erased from the list of human fossils. It is an artificial combination of fragments of a modern-human braincase with orang-utang-like mandible and teeth. *Sinanthropus* and *Pithecanthropus* show that relatively advanced types of mandible and teeth can be part of a skull with a primitive braincase, but the conditions are never reversed. The strict correlation which exists between size and form of braincase and size and form of jaws excludes the production of a chimaera composed of a large-brained calvaria and an elongated mandible of anthropoid type.

3. The Swanscombe Skull is not a primitive hominid skull but has all the characteristics of a modern-human skull—so far as those cranial bones which have been preserved permit of judgment. If it could be proved that the missing frontal bones had a frontal torus, the skull could be placed in the same group with the Steinheim Skull or the Skhūl population of Mount Carmel. As long as this proof is *not* brought forward, the nature of the skull remains doubtful.

4. *Africanthropus njarasensis* is neither an African *Sinanthropus* nor an African *Pithecanthropus*, even if Weinert's reconstruction of the fragments is considered correct. It may be placed in the neighborhood of the Rhodesian or Florisbad skull, or it may represent still another type.

5. *Pithecanthropus* Skull II represents the same hominid type as Dubois' Trinil Skull (*Pithecanthropus* Skull I) except that it has somewhat smaller dimensions throughout. Dubois' claim that von Koenigswald has restored Skull II in such a way as to make it similar in form to the Trinil Skull is without any foundation. *Pithecanthropus* Skull III is the fragment of a juvenile skull which shows all the characteristics of *Pithecanthropus* Skulls I and II. *Pithecanthropus* Skull IV is much bigger and more massive than Skulls I and II, and all the muscular markings are much more pronounced. These differences could be somewhat lessened by explaining them as due to sex, and Skull IV would, then, represent a male and Skull I and II females,

unless there were other features and circumstances which make such an interpretation questionable. The strange sagittal crest, consisting of a chain of large, more or less distinct knobs; the persistence of a maxillary diastema; the large dimensions of the maxilla; the complete smoothness of the palate; and von Koenigswald's recent discovery—a mandible of incontestably hominid character which yet exceeds in bulk and massiveness any so far known from any hominid or anthropoid—suggest the possibility that these giant, primitive hominids were linked with the typical *Pithecanthropus* by smaller, intermediate forms such as Skull IV.

The *Pithecanthropus* skull, as we know it now, agrees broadly with that of *Sinanthropus* (see no. 1 of this summary). But there are some points of specific divergence. The braincase of *Pithecanthropus* is generally smaller and its walls thicker than is true in *Sinanthropus*, although the length-height indices are about the same: the average cranial capacity amounts to 870 cc. in the former as against 1075 cc. in the latter. The horizontal contour of the occiput is round ("Sphenoides" type) in *Pithecanthropus* but elongated ("Ellipsoides" type) in *Sinanthropus*. The *Pithecanthropus* frontale is flat and continues almost directly into the frontal torus while that of *Sinanthropus* has developed a bump-like protruding tuberosity separated from the frontal superstructure by a distinct groove. The air-sinus is very spacious in *Pithecanthropus* but small or completely wanting in *Sinanthropus*. Form and pattern of the *Sinanthropus* teeth show some peculiarities which are wanting or less pronounced in *Pithecanthropus*.

In any case, the differences in the features of the skull between these two hominid types are of minor importance in the face of their similarity when compared with the skulls of the Neanderthal and related groups. *Pithecanthropus* and *Sinanthropus*, therefore, are representatives of about the same general stage of human evolution but of two different regional or racial variations of that stage. Which form is the more primitive cannot be decided while the *Pithecanthropus* material remains as scanty and as fragmentary as it is at present. If, however, Skull IV is set aside: while some features seem more primitive in *Pithecanthropus*, *Sinanthropus* seems the more primitive in others, particularly in dentition.

6. *Homo soloensis* (Ngandong skulls) cannot be placed in the Neanderthal group but represents a rather more primitive type. Out of 58 characters of the calvaria alone, 55 or 56 are held in common with *Pithecanthropus* and *Sinanthropus*. In only two or three are differences really recognizable, namely in the size of the calvaria and in the cranial capacity. The average maximum length, for example, is 15.4 mm. larger when compared with *Sinanthropus* and 29.0 mm. larger when compared with *Pithecanthropus*. This superiority of the *Homo soloensis* skull holds good in all dimensions. Nevertheless, the cranial capacity is not correspondingly larger because of the great thickness of the braincase and the superstructures. I estimate the average capacity of the Ngandong skull as about 1100 cc. with a range from 1035 cc. to 1255 cc. These figures are very close to those of *Sinanthropus* but distinctly higher than those of *Pithecanthropus* (see no. 5 above). The Ngandong Skull agrees with the skulls of *Sinanthropus* and *Pithecanthropus* particularly in the position of its greatest breadth, in the low length-height index, and in the special features of the basal parts of the temporal bone. It differs from *Sinanthropus* in the same characteristics in which *Sinanthropus* differs from *Pithecanthropus*. *Homo soloensis* appears, therefore, as an enlarged *Pithecanthropus* type on the way to an advanced form. The fact that the geological level in which the Ngandong skulls were found is higher than that of the Trinil specimen also fits into this morphological picture.

7. The group of fossil hominids usually designated under the collective name "Neanderthalians" fits conformably in the line of human evolution with *Pithecanthropus-Sinanthropus* on

the base and modern man at the top. As to the metrical characters, there is, except for one—the length-opisthion height index—, no hiatus between the different hominid groups but a continuous overlapping of neighboring types. This proves: (1) The existence of a continuous, evolutionary line leading from the *Pithecanthropus-Sinanthropus* stage to modern man is already proved by the fossil human material now at hand. (2) The Neanderthal stage cannot be distinguished from lower or more advanced stages by mere measurements but only by a consideration of their special combinations as well as the non-metrical characters. The way in which primitive features disappear and are replaced by newly acquired ones is the same in every case. Some features, like the frontal torus, persist much longer than others, as for instance the occipital torus and its differentiations. Therefore, the course of the gradual transformation sometimes appears confused when single phases—such as would be theoretically expected—do not succeed in an unmistakable sequence. These seeming unconformities are due to (1) individual variations, (2) deficiency of the recovered material, (3) certain disharmonies in the combination of correlated characters.

Hence it happens that, as in the case of the Heidelberg Mandible, a very large and robust jaw with all signs of primitive character may be combined with teeth which come closer to modern man in form, size and arrangement. Or, as in the case of the Ehringsdorf mandibles, primitive teeth are combined with more advanced symphyseal structures. The cranial capacity of the Neanderthalians ranges from 1200 cc. to 1610 cc.; in modern man, when only the averages of the racial groups are taken into account, it runs from 1125 cc. (Australian) to 1540 cc. (Eskimo) —a much more ample range of variation. But in the Neanderthalians the relatively high capacity is combined with characteristically primitive features in form and configuration of the braincase which are never found in modern man. An intermingling of primitive and advanced characters in the same specimen or subgroup indicates a still unbalanced state of transformation.

Despite those disharmonies and the intermediate character of the Neanderthalians as a whole, they can be subdivided into at least four subgroups, according to the prevalence of more primitive or more advanced characters. The only representative of the first and lowest subgroup ("Rhodesian group") is the Rhodesian Man; the second subgroup ("Spy group") embraces the forms Morant called Mousterians, including the Saccopastore and Monte Circeo skulls; to the third subgroup ("Ehringsdorf group") belong—in addition to the Ehringsdorf Skull—the Steinheim Skull, probably the Krapina skulls, the Tabūn I Skull and the Kafzeh skull (Judea); the fourth subgroup, already considered as intermediate between Neanderthalians and modern man, is represented by the Skhūl population of Mount Carmel ("Skhūl group") and probably by the Galilee skull also. *Homo soloensis*, as shown in no. 6 of this Summary, is not a Neanderthalian in the strict sense. He is much closer to the *Sinanthropus-Pithecanthropus* stage and therefore intermediate between this and the Neanderthalian stage.

8. The limb-bones of all fossil hominids, speaking only of those the attribution of which is not doubted, exhibit a perfectly human character. There are differences in length, robustness and other, minor details but in no way do the bones approach the anthropoid characters to the extent shown by the cranial bones and the teeth. This indicates that the adoption of an erect posture far preceded the transformation of the skull.

9. Any judgment as to the relationships between *Homo sapiens* and the preceding stages of human evolution as far down as *Sinanthropus* and *Pithecanthropus* can be based on morphological data only. Genetical formulas, ecological factors and sexual affinities or aversions, such

as are used in the discrimination of living organisms, are not applicable to palaeoanthropology. Nor are geological considerations alone to be accepted as decisive evidence.

10. *Homo sapiens*, although he splits into a great number of groups and subgroups which diverge morphologically, represents but *one* species. There is no reason to believe that fossil hominids were different or that the establishment of a unique species did not set in much earlier than the time when the *Homo sapiens* stage was attained. The names given to groups and subgroups of fossil hominids have no "generic" or "specific" meaning. They are nothing but convenient labels, respected by tradition, to facilitate identification. I have used the names *Sinanthropus, Pithecanthropus* etc. in this sense and shall continue to do so in the future.

11. The existence of hominids with some advanced features in a very early geological period, *e.g.* Heidelberg Mandible with an almost modern-human tooth pattern in the Interglacial Mindel I/Mindel II and Steinheim Skull with certain cranial bones of modern-human character in the Interglacial Riss I/Riss II, indicates that hominid forms as primitive as *Pithecanthropus* and *Sinanthropus* must have lived in Europe or in the Western half of the Old World at an age still earlier than that in which advanced hominids like those of Heidelberg and Steinheim appeared.

12. There is no evidence of any specialization or side-branching in the development of homid forms from the *Sinanthropus-Pithecanthropus* stage up to that of modern man. What has been asserted to be such an occurrence will not stand against critical analysis. The reduction of primitive features follows a strictly kept line from the first modification to complete obliteration and this line corresponds with the appearance of newly acquired features. Neither morphological nor geological incongruities can be offered as evidence of real discontinuities of the evolutionary human line.

13. *Homo sapiens* is a collective name for numerous racial groups which have certain general features in common. The possession of these features proves that all these groups belong to the same advanced stage of human evolution but does not mean that all came from one form with "Neanderthalian" qualities. As *Pithecanthropus* and *Sinanthropus* represent two groups of the same early human stage, and as the Neanderthal and Late Palaeolithic mankind consists of similarly differentiated groups, so, it can be assumed, the various racial groups of modern mankind took their origin from ancestors already differentiated in the same manner. The Australian aborigines of today, regarded by some authors as relics of the "European" Late Palaeolithic man, driven from Europe to far-off Australia, are, in one sense, rather autochthons of South East Asia. There is an almost continuous line leading from *Pithecanthropus* through *Homo soloensis* and fossil Australian forms to certain modern primitive Australian types. Rhodesian Man seems to be linked, through types like the Florisbad Man, to certain South African races of today. Neanderthalians of the European or kindred types have contributed to the Skhūl population of Mount Carmel in Palestine with its modern-human stamp.

There is now evidence that: (1) Neanderthaloids have been directly transformed into *Homo sapiens* forms; (2) Neanderthalians should not be considered to have become extinct without leaving any descendants behind; (3) racial or regional differentiations are recognizable within the Neanderthalians themselves and are traceable from there to races of modern mankind.

In the case of *Sinanthropus* there is, thus far, no Neanderthal form known which links him to a special *Homo sapiens*-form. But there are clear evidences that *Sinanthropus* is a direct ancestor of *Homo sapiens* with closer relation to certain Mongolian groups than to any other races. Not less than twelve peculiarities, characteristics of the cranial and limb bones of

Sinanthropus, and of the teeth also,—some having a high percentage of occurrence in the available specimens—occur with a relatively high degree of frequency in Mongolian groups. These characteristics are: mid-sagittal crest and parasagittal depression; Inca bone; certain "Mongolian" features of nasal bridge and cheek region of the maxilla and zygomatic bone; maxillary ear- and mandibular exostoses; a high degree of platymerism of the femur combined with a strong deltoid tuberosity of the humerus; and finally, shovel-shaped upper lateral incisors. This statement, however, does not mean that modern Mongols derived exclusively from *Sinanthropus* nor that *Sinanthropus* did not give origin to other races also.

14. The occurrence of advanced hominid forms in early geological periods and, on the other hand, of more primitive ones in later times is compatible if it is assumed that human evolution (1) began much earlier than is generally accepted and (2) has been subjected to retardation and acceleration as time and space have interfered.

Since *Pithecanthropus* and *Homo soloensis* are geologically later products of human differentiation than Heidelberg or Steinheim Man, for example, the recent-human descendants of the Asiatic primitive hominids must be younger than those of the latter. The Australian aborigine as an offspring of the *Pithecanthropus* line is not a relic of European Late Palæolithics, marooned on the Australian continent, but is a late branch of the human stem passing now through the same evolutionary stage as that through which the Europeans have passed during the Late Pleistocene.

15. The principle underlying the transformation of the human skull during evolution, is that the braincase assumes a more glabellar form by rolling itself up about a transverse axis which passes, approximately, through the mandibular fossae. The process can be described as a gradual expansion of the braincase, the individual bones which build the walls turning around their respective basal axes. At the same time, the skull-base is shortened in longitudinal and transverse directions while klition and porion shift upward proportionally to the increasing deflection of the base. While the braincase expands it loses its massiveness, as its walls and bones which participate in the formation of the base become thinner. The entire reinforcement-system as an integral part of the cranial wall undergoes a corresponding reduction.

The size of braincase and of face are closely correlated: the larger the jaws the smaller the braincase and vice versa. The reduction of the face consists of a decrease of length, height and breadth of which the shortening of the length along the prosthion-basion and incision-basion lines is the most conspicuous feature. This reduction is connected with the reduction of the alveolar processes of maxilla and mandible and these, in their turn, with the reduction of the crowns and roots of the teeth. The bodies of the maxilla and mandible are less involved in the process of reduction. The prominent nasal bridge, the nasal spine and the chin appear, in a certain sense, as landmarks left from this reduction and, therefore, as characteristic features of the recent-human face.

It is a well-known fact that there is a strict correlation between the size or weight of the brain and the size or weight of the body. Small animals have relatively larger brains than large animals. The size of the brain is manifested in the size of the braincase and the size of the body in the size of the jaws and, consequently, in the strength of the superstructures of the braincase. The relatively large brain in the skull of a small animal needs much more space than a relatively small brain in the skull of a large animal. On the other hand, the masticatory apparatus requires very little space in a small animal while it requires by far the largest part of the skull in a large animal. The more the brain and, consequently, the braincase expands the greater becomes the diminution of the jaws and that of the superstructures of the braincase. The trans-

formation the hominid skull undergoes on its way from an anthropoid ancestor to modern man corresponds in all its phases to these general rules. The only decisive difference is that the increase of the human brain is not a relative but a real one. Otherwise, the way in which the braincase expands and the jaws reduce is exactly the same in principle as in dwarf and large types of any other mammalian group.

16. The evolution of the hominid skull, so far at least as it is indicated by its later stages, follows a continuous line. There is not any one structure which could be interpreted as chance variation; neither is there any indication of leaps in the course of this development. All essential changes have "macroevolutionary" character, although they appear under the form of "microevolutionary" variations.

17. *Sinanthropus* and *Pithecanthropus*, like all hominid forms, are to be classified as anthropoids when their general zoological character is taken into account. But there is no indication that they are more closely related to one of the three living anthropoids than to the other two. In the main features in which *Sinanthropus* and *Pithecanthropus* differ from the anthropoids—character and proportions of the limb-bones; character of the dentition, particularly that of the canine group; development of the jaws; massiveness and reinforcement-system of the skull; position of the occipital foramen; form of the occipital bone—*Sinanthropus* differs from all three anthropoid types alike. On the other hand, there are characters in which *Sinanthropus* conforms most to chimpanzee; others in which he conforms to gorilla; and finally, still others in which he conforms to the orang-utang. This indicates that the original main stem of the uppermost primate group split very early in two branches—a hominid branch and an anthropoid branch proper.

The fact that chimpanzee comes closest of all three anthropoids to *Sinanthropus* and the hominids with regard to the number of characters held in common does not necessarily prove that a more intimate relationship exists. Common characters can be explained equally well by the assumption that chimpanzee retained more of the original characters of the common ancestor than did the two remaining anthropoids which proceeded farther on their way to special differentiation.

The fossil anthropoids are, thus far, of little use in the search for this common ancestor. The only material at hand consists of teeth and fragments of maxillae and mandibles. However since the dentition of *Dryopithecus* and related forms already shows the characters of the branch which leads to the living anthropoids, *Dryopithecus* can hardly be considered as ancestor of the less differentiated hominids.

The *Australopithecinae* as represented by *Australopithecus africanus*, *Plesianthropus transvaalensis* and *Paranthropus robustus* conform with the hominids not only in the general character of their dentition but also in some special features of the temporal bone and mandible. On the whole however they seem to be closely related to the gorilla branch of the anthropoid stem. They must, therefore, have branched off from the common hominid-anthropoid stock near its point of division and that point where gorilla derivated.

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    1940   Human genera and species. Nature, Vol. 145, No. 3674. pp. 510–511.

EXPLANATIONS OF FIGURES

Fig. 1.   Right (?) parietal bone of *Sinanthropus* Skull I (B II ?).   Viewed from the cerebral side.   Photograph from the original.   2/3.   Abbreviations: ma, margo anterior; mi, margo inferior; mp, margo posterior; ms, margo superior; ra, ramus anterior arteriae meningeae mediae; rp, ramus posterior arteriae m.m.

Fig. 2.   Fragment of the left side of the frontal bone of *Sinanthropus* Skull I (B II ?).   Lateral view.   Photograph from the original.   1/1.   Abbreviations: ft, facies temporalis; lt, linea temporalis; pz, processus zygomaticus; tf, tuber frontale.

Fig. 3.   The same fragment as in Figure 2.   The fragment in right orientation viewed from in front.   Drawing from the original.   1/1.   Designation see Figure 2.

Fig. 4.   The same fragment as in Figure 2.   The fragment in right orientation viewed from the left side.   Drawing from the original.   1/1.   Designation see Figure 2.

Fig. 5.   *Sinanthropus* Skull II—Skull of Locus D.   Norma lateralis sinistra.   Photograph from the original taken by Davidson Black.   1/2.
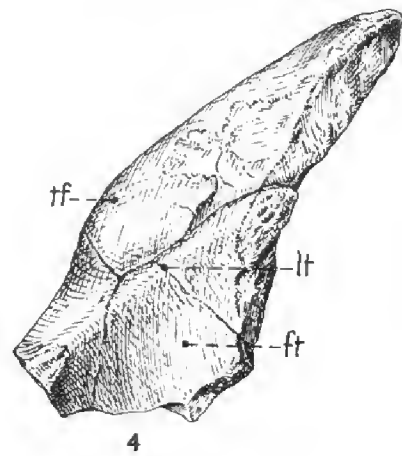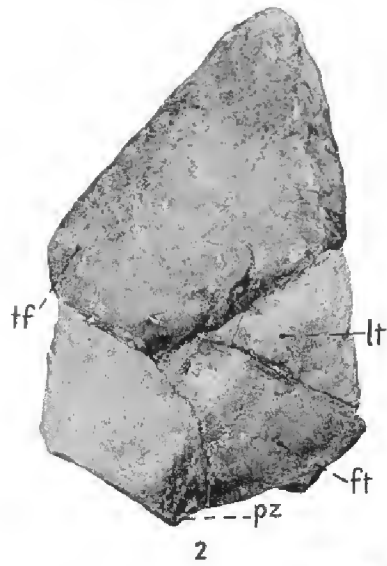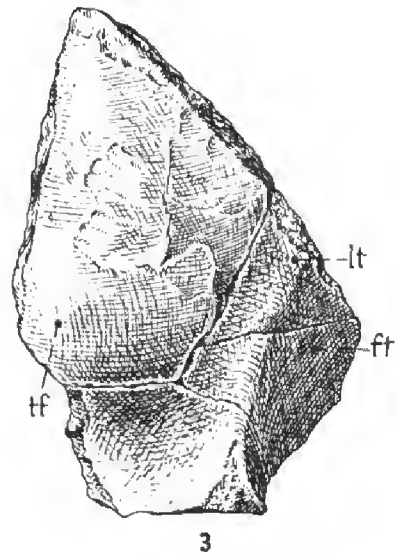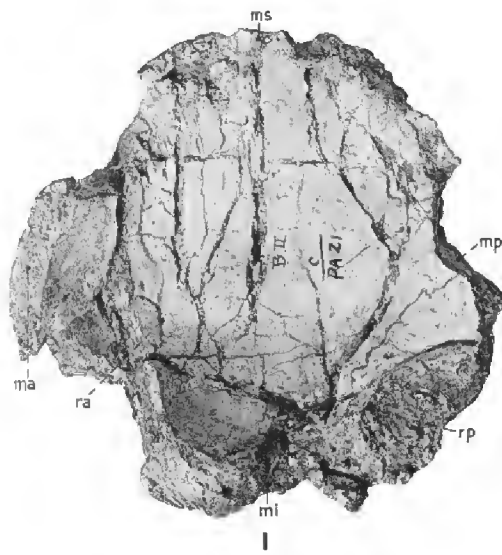
Fig. 6. *Sinanthropus* Skull II—Skull of Locus D. Norma lateralis dextra. Photograph from the original taken by Davidson Black. 1/2.

Fig 7. *Sinanthropus* Skull II—Skull of Locus D. Norma frontalis. Photograph from the original taken by Davidson Black. 1/2.

Fig. 8. *Sinanthropus* Skull II—Skull of Locus D. Norma occipitalis. Photograph from the original taken by Davidson Black. 1/2.

Fig. 9. *Sinanthropus* Skull II—Skull of Locus D. Norma verticalis. Photograph from the original taken by Davidson Black. 1/2.

Fig. 10. *Sinanthropus* Skull II—Skull of Locus D. Norma basalis. Photograph from the original taken by Davidson Black. 1/2.

FIG. 11. *Sinanthropus* Skull II—Skull of Locus D. Drawing from the original. Norma lateralis sinistra (see Figure 5). 1/1. Abbreviations: lt, linea temporalis; sl, sutura lambdoidea; snf, sutura nasofrontalis; snm, sutura nasomaxillaris; spm, sutura parietomastoidea; ss, sutura squamosa; sss, sutura sphenosquamosa; ssz, sutura sphenozygomatica; tp, torus angularis ossis parietalis.
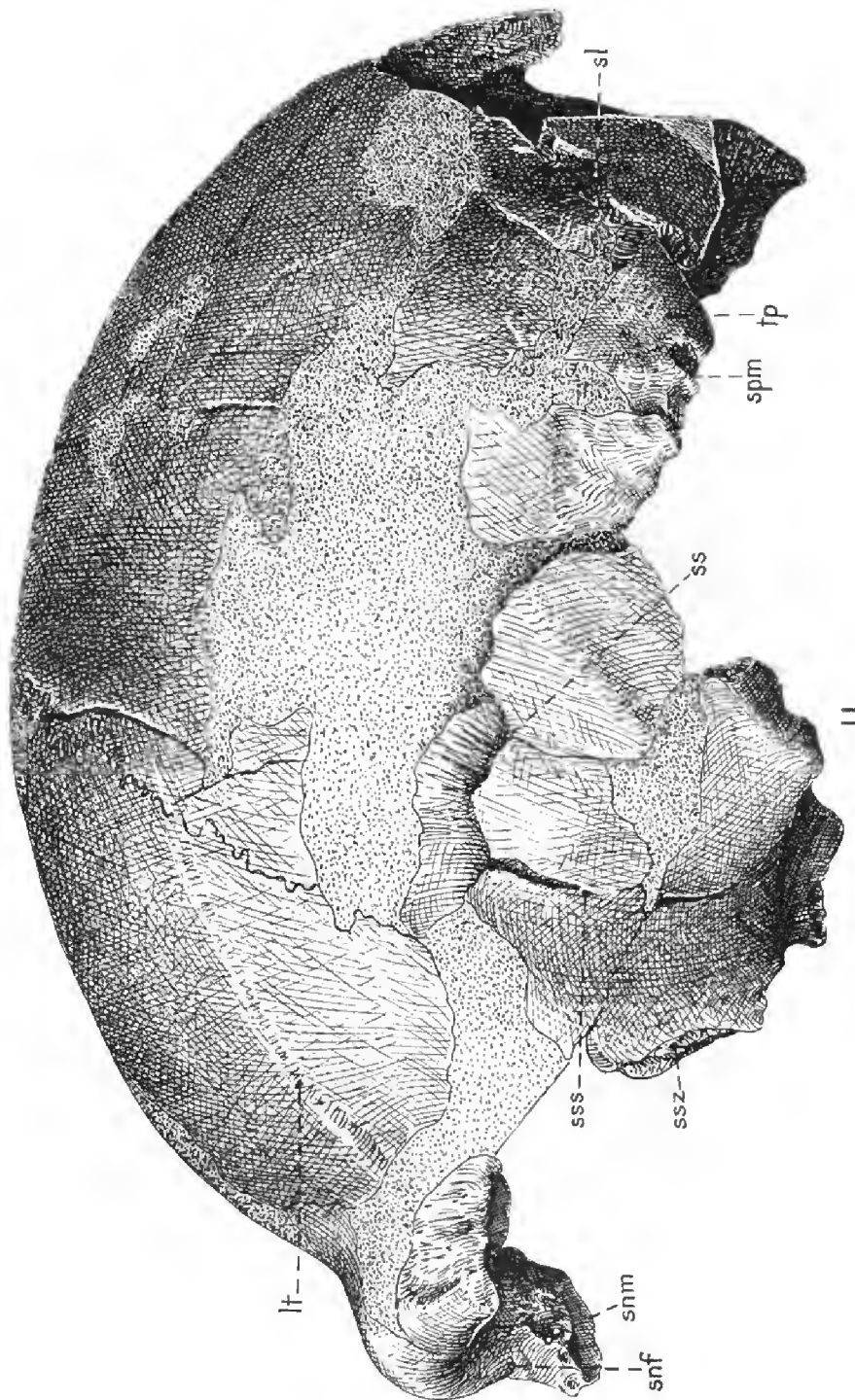
FIG. 12. *Sinanthropus* Skull II—Skull of Locus D. Drawing from the original. Norma lateralis dextra (see Figure 6). 1/1. Abbreviations: fo, facies orbitalis ossis zygomatici; sl, sutura lambdoidea; sm, sutura mendosa; snf, sutura nasofrontalis; snm, sutura nasomaxillaris; ss, sutura squamosa; tp, torus angularis ossis parietalis.
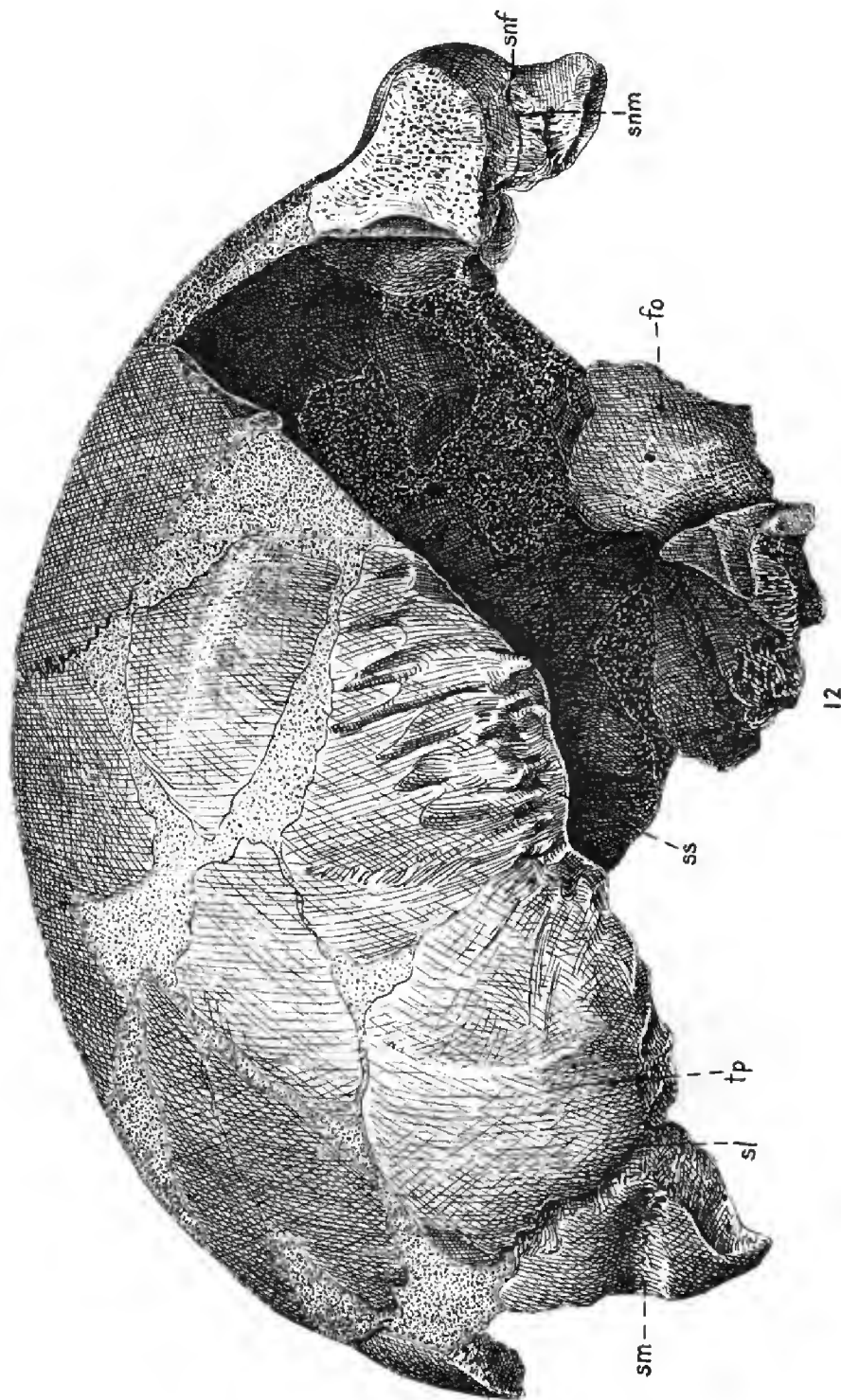
FIG. 13.   *Sinanthropus* Skull II—Skull of Locus D.   Drawing from the original.   Normal frontalis (see Figure 7). 1/1.   Abbreviations: cob, crista orbitalis; cp, canalis pterygoideus; fo, facies orbitalis; fr, foramen rotundum; snf, sutura nasofrontalis.

FIG. 14.   *Sinanthropus* Skull II—Skull of Locus D.   Drawing from the original.   Normal occipitalis (see Figure 8).   1/1.   Abbreviations: fr, foramen rotundum; sl, sutura lambdoidea; sm, sutura mendosa; ss, sutura squamosa.
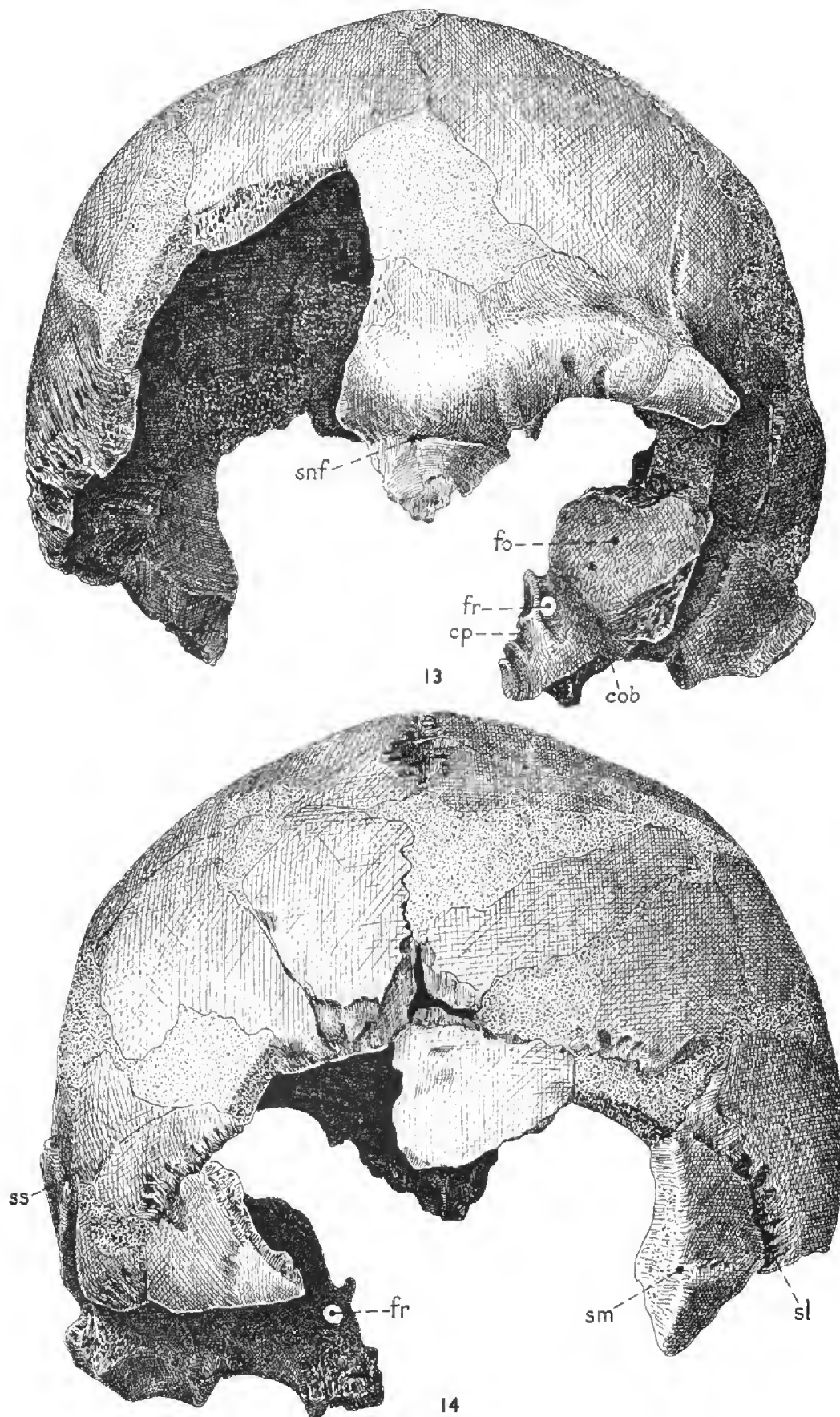
Fɪɢ. 15. *Sinanthropus* Skull II—Skull of Locus D. Drawing from the original. Normal verticalis (see Figure 9). 1/1. Abbreviations: lt, linea temporalis; sa, artificial sulcus; sl, sutura lambdoidea; tp, torus angularis ossis parietalis.
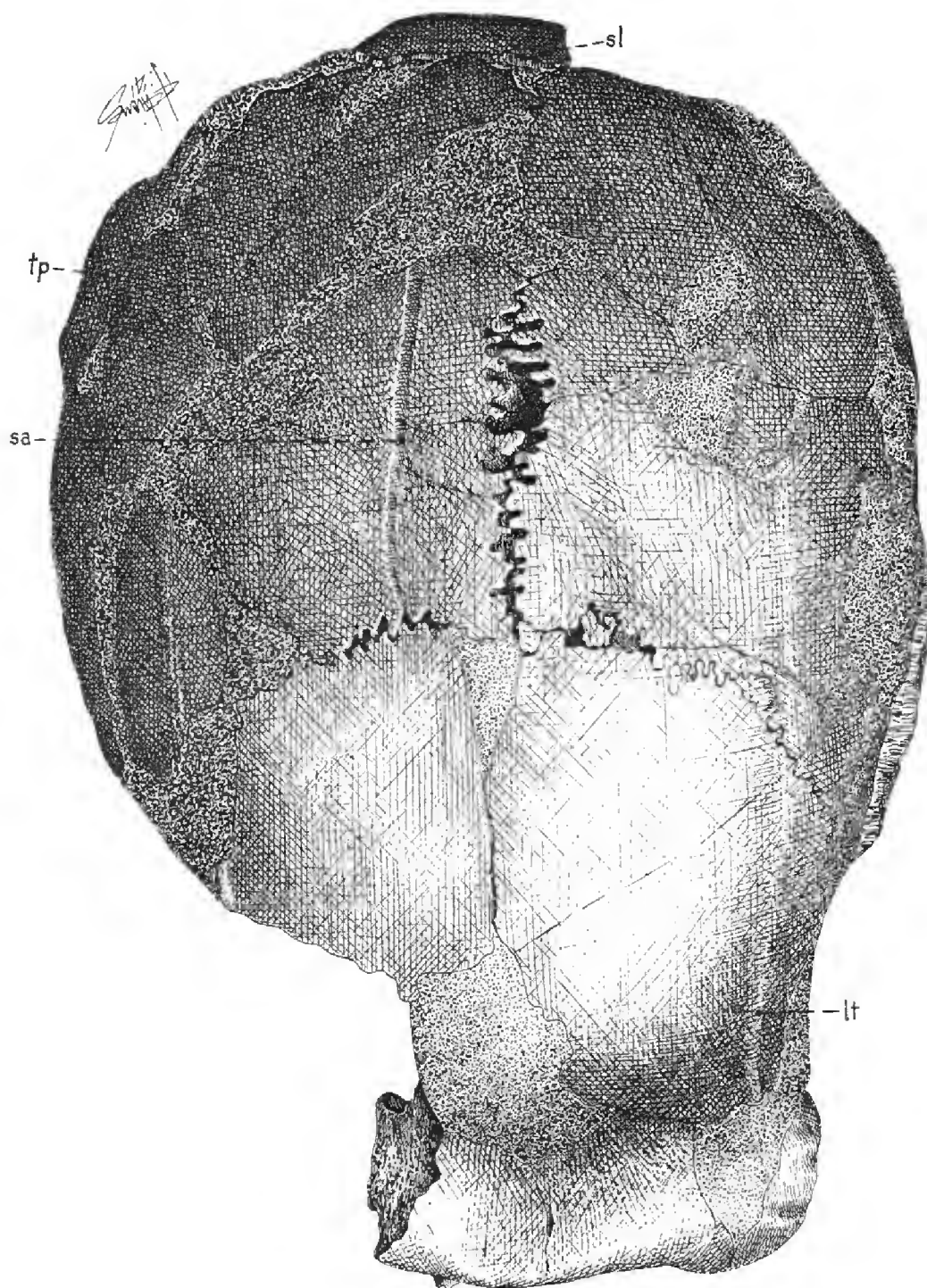
Fig. 16. *Sinanthropus* Skull II—Skull of Locus D.   Drawing from the original.   Norma basalis (see Figure 10). 1/1.   Abbreviations: cf, crista frontalis; fm, fossa mandibularis; foi, fissura orbitalis inferior; for, foramen sphenoidalis ovale; ft, facies temporalis ossis sphenoidalis; lid, limen coronale; lp, lamina perpendicularis; mn, meatus nasi; pp, processus pterygoideus; si, sinus frontalis; sfe, sutura frontoethmoidalis; sif, spina infratemporalis; ss, sutura squamosa; ta, tuberculum articulare; tp, torus angularis ossis parietalis.
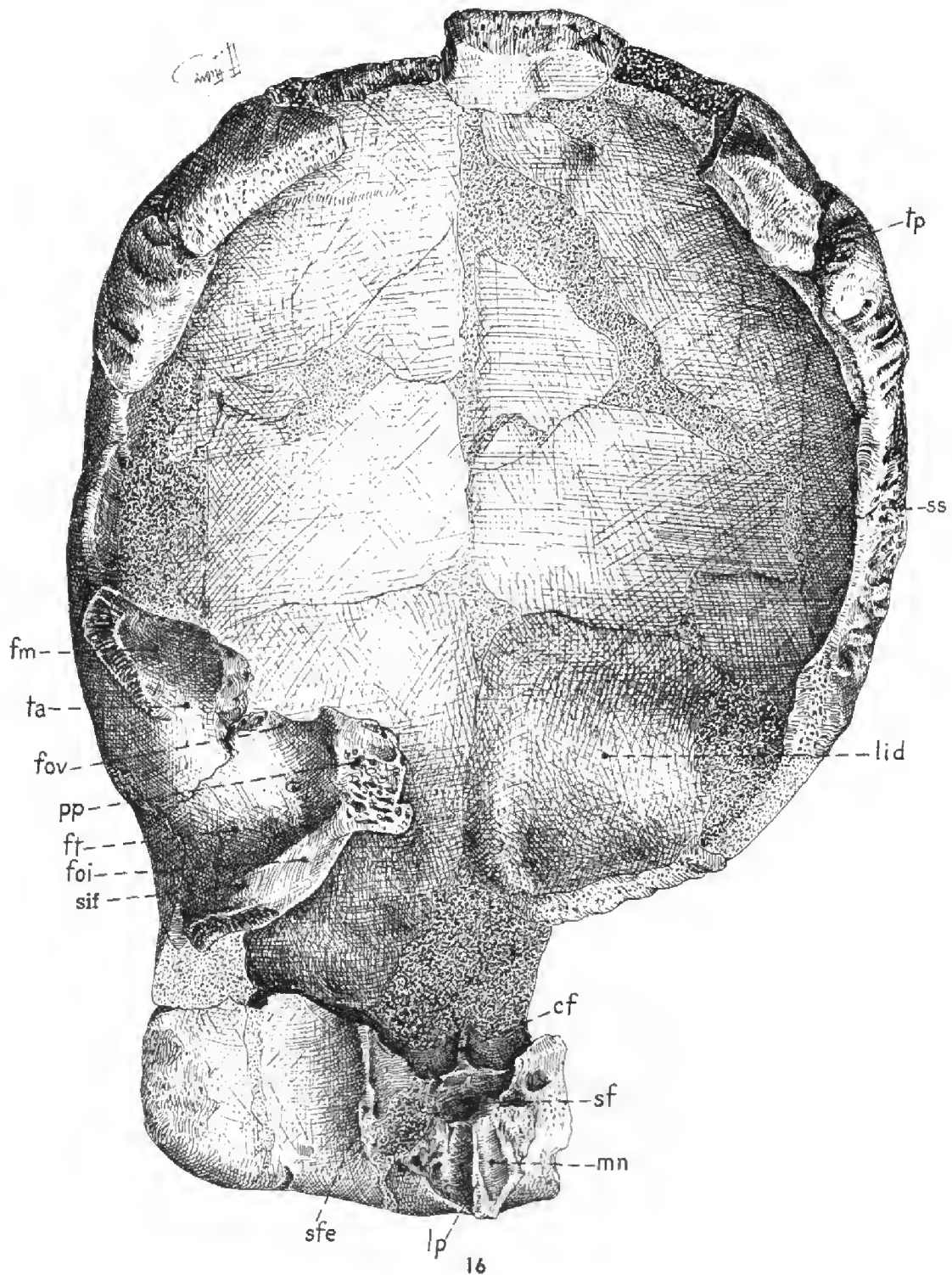
FIG. 17. Fragment of the anterior moiety of the right parietal bone of *Sinanthropus* Skull IV (Skull G II). Laterial view. Photograph from the original. 2/3.

FIG. 18. Fragment of the anterior moiety of the right parietal bone of *Sinanthropus* Skull IV (Skull G II). Lateral view. Drawing from the original (see Figure 17). The whole contour of the bone reconstructed. 1/1. Abbreviations: d, depressio parasagittalis; lti, linea temporalis inferior; lts, linea temporalis superior; sc, sutura coronalis; ss, sutura squamosa; ssg, sutura sagittalis.

FIG. 19. Fragment of the right parietal bone of *Sinanthropus* Skull IV (Skull G II). The fragment in right orientation, viewed from in front. Drawing from the original. 1/1. Abbreviations: csg, crista sagittalis; d, depressio parasagittalis; lt, linea temporalis; sc, sutura coronalis; ss, sutura squamosa; ssg, sutura sagittalis; tbp, tuber parietale.

FIG. 20. Fragment of the right parietal bone of *Sinanthropus* Skull IV (Skull G II). The posterior breakage showing the thickness of the bone and the three layers. Drawing from the original. 1/1. Abbreviations: di, diploë; te, tabula externa; ti, tabula interna.

FIG. 21. *Sinanthropus* Skull V—Skull III Locus H; Fragment I. Left temporal bone and adjacent bones (portions of the temporal and occipital bones). Photograph from the original. 2/3. Abbreviation: ac, artificial cut.
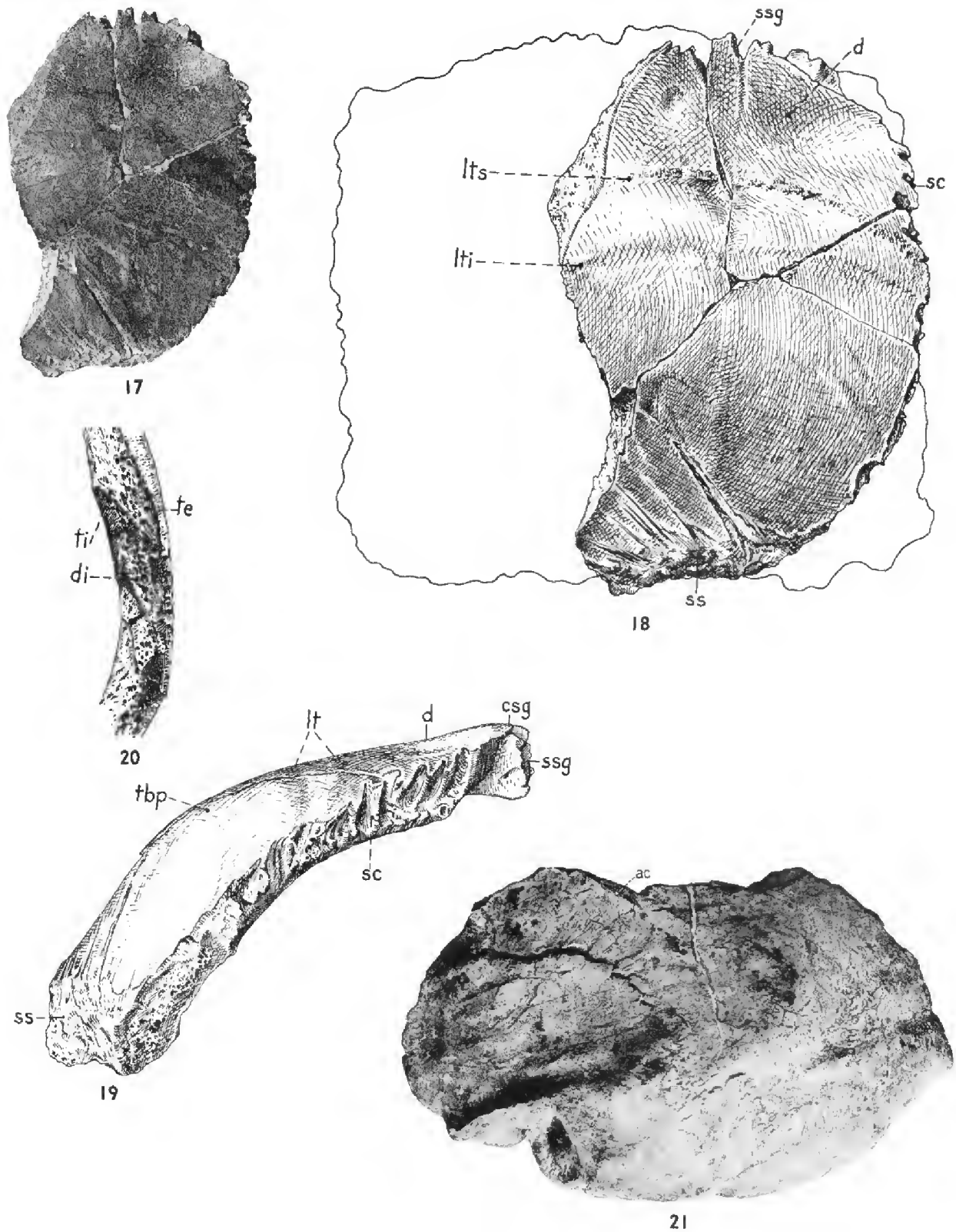
Fig. 22. *Sinanthropus* Skull V—Skull III Locus H; Fragment I. The same fragment as in Figure 21; cerebral side. Photograph from the original. 2/3.

Fig. 23. *Sinanthropus* Skull V—Skull III Locus H; Fragment I. The same fragment as in Figure 21. Occipital view; the fragment in right orientation. Photograph from the original. 2/3. Abbreviations: cs, crista mastoidea; sl, sutura lambdoidea; st, sulcus supratoralis.

Fig. 24. *Sinanthropus* Skull V—Skull III Locus H; Fragment I. Ear region and mastoid portion. Drawing from the original. 1/1. Abbreviations: cm, crista mastoidea; com, crista occipitomastoidea; cs, crista supramastoidea; fm, fossa mandibularis; im, incisura mastoidea; ip, incisura parietalis; rm, recessus med. fossae mand.; scp, spina cristae petrosae; ta, tuberculum articulare.

Fig. 25. *Sinanthropus* Skull V—Skull III Locus H; Fragment I. The fragment viewed from below and behind. Drawing from the original. 1/1. Abbreviations: cm, crista mastoidea; com, crista occipitomastoidea; cs, crista supramastoidea; im, incisura mastoidea; lt, linea temporalis; ls, linea nuchae superior; pm, processus mastoideus; scp, spina cristae petrosae; sl, sutura lambdoidea; st, sulcus supratoralis; t, torus occipitalis; tp, torus angularis ossis parietalis.
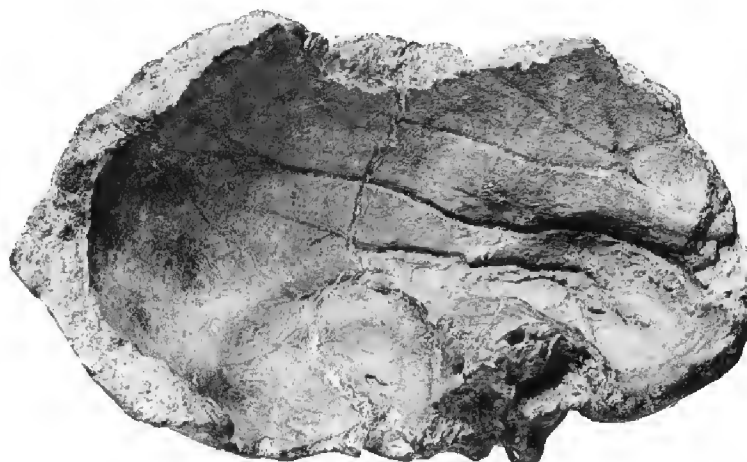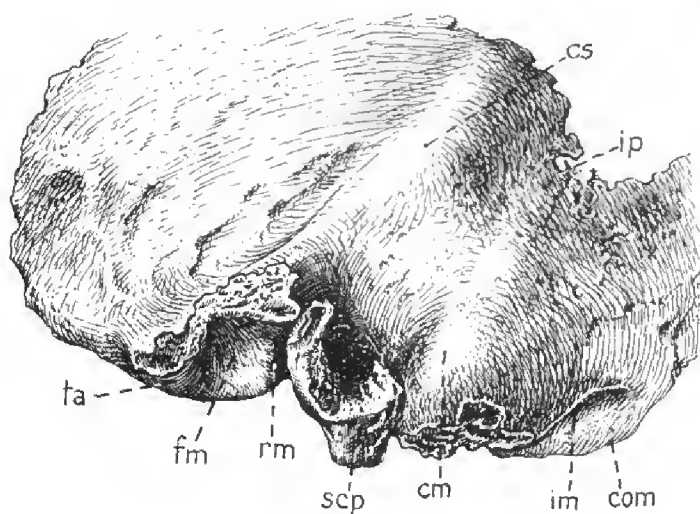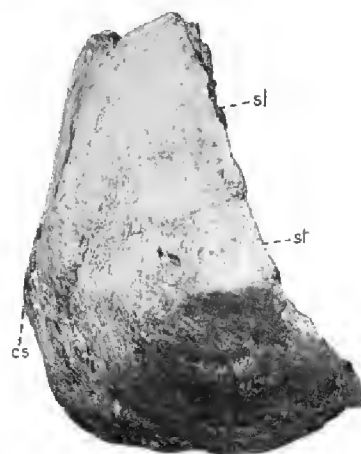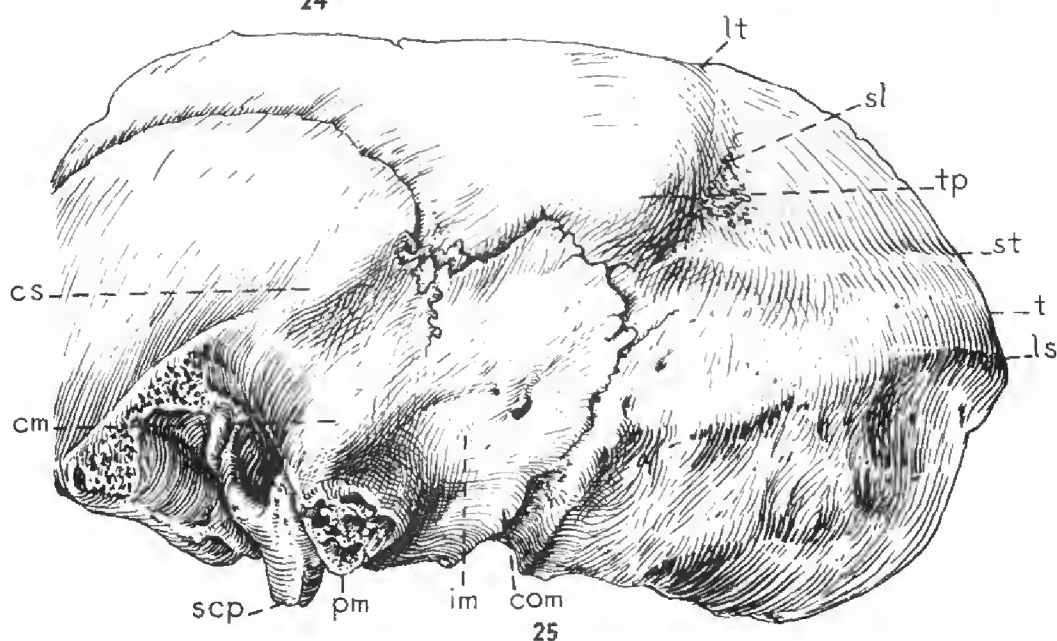
FIG. 26. *Sinanthropus* Skull V—Skull III Locus H; Fragment I. Basal view. Drawing from the original. 1/1.
Abbreviations: cc, canalis caroticus; com, crista occipitomastoidea; fj, fossa jugularis; fm, fossa mandi-
bularis; fp, foramen processus styloidei; fs, foramen spinosum; fsm, foramen stylomastoideum; im,
incisura mastoidea; pae, porus acusticus externus; pm, processus mastoideus; scp, spina cristae petrosae;
sss, sutura sphenosquamosa; ta, tuberculum articulare.

FIG. 27. *Sinanthropus* Skull V—Skull III Locus H; Fragment I. Cerebral side. Drawing from the original (see
Figure 22). 1/1. Abbreviations: av, apertura ext. aquaeducti vestib.; cc, canalis caroticus; csy, crista
sylvii; ea, eminentia arcuata; ec, eminentia cruciata; fc, fossa cerebralis; fcl, fossa cerebellaris; fj, fossa
jugularis; fma, foramen mastoideum; fs, foramen spinosum; mai, meatus acusticus internus; sig, sulcus
sigmoideus; sps, sutura petrosquamosa; to, torus occipitalis; vmm, vasa meningea media.

FIG. 28. *Sinanthropus* Skull V—Skull III Locus H; Fragment II. Fragment of the right temporal bone: ear
region and mastoid portion. Photograph from the original. 1/1.

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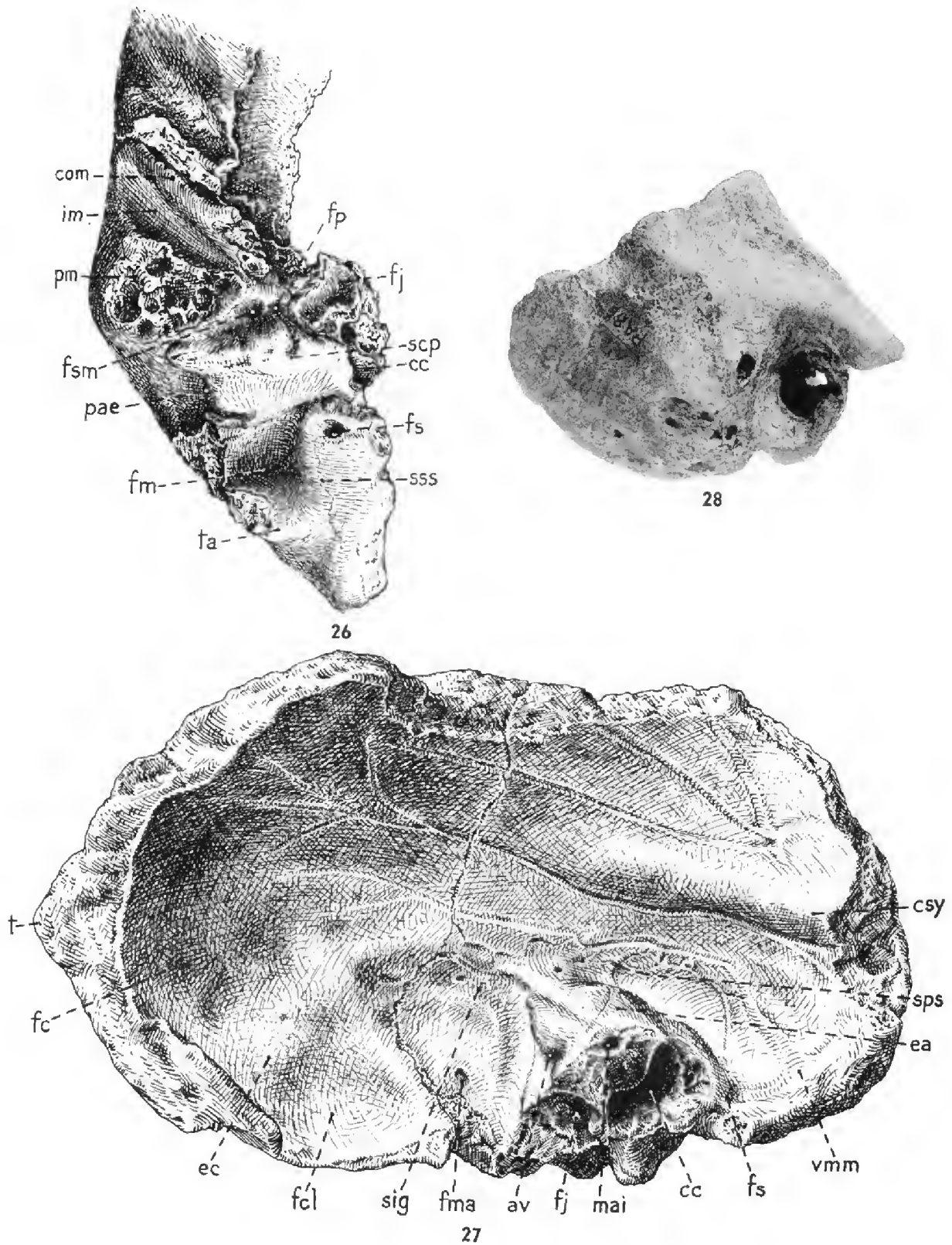
Fig. 29. *Sinanthropus* Skull V—Skull III Locus H; Fragment II. Lateral view. Drawing from the original (see Figure 28). 1/1. Abbreviations: cm, crista mastoidea; cs, crista supramastoidea; im, incisura mastoidea; pm, processus mastoideus; ssm, spina supra meatum (?).

Fig. 30. *Sinanthropus* Skull V—Skull III Locus H; Fragment II. Basal view. Drawing from the original. 1/1. Abbreviations: cc, canalis caroticus; fj, fossa jugularis; fsm, foramen spinomastoideum; im, incisura mastoidea; pae, porus acusticus externus; pm, processus mastoideus; som, sutura occipitomastoidea.

Fig. 31. *Sinanthropus* Skull VI—Skull VI Locus I; Fragment I. Part of the right moiety of the frontal bone. Viewed from above. Photograph from the original. 1/1. Abbreviations: lti, linea temporalis inferior; lts, linea temporalis superior; sc, sutura coronalis (pars temporalis).

Fig. 32. *Sinanthropus* Skull VI—Skull VI Locus I; Fragments II and III. Part of the left parietal bone. Lateral view. Photograph from the original. 1/1. Fragment III is the smaller piece attached to the anterior inferior border of the larger Fragment II.

Fig. 33. *Sinanthropus* Skull VI—Skull VI Locus I; Fragment IV. Anterior part of the squamous portion of the right temporal bone. Lateral view. Photograph from the original. 1/1.

Fig. 34. *Sinanthropus* Skull VI—Skull VI Locus I; Fragment I (see Figure 31). Fragment viewed from the right side in correct orientation. Drawing from the original. 1/1. Abbreviations: da, artificial depression; lti, linea temporalis inferior; lts, linea temporalis superior; op, os parietale; pz, processus frontozygomaticus (broken off); sc, sutura coronalis; tf, tuber frontale.
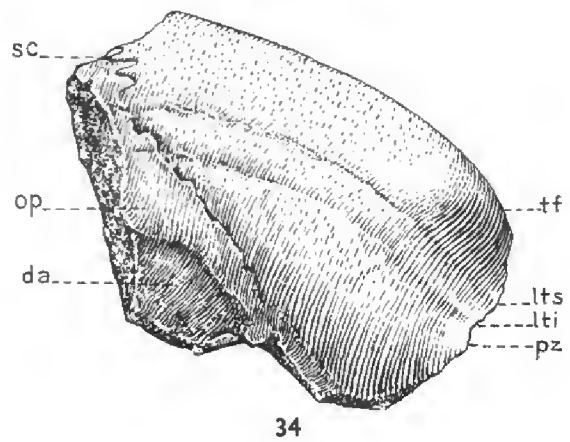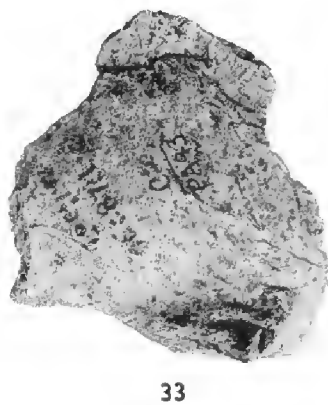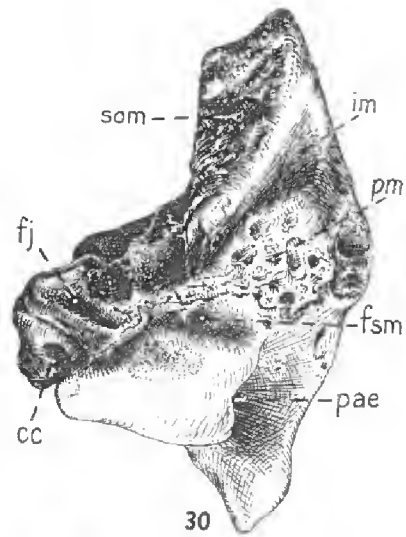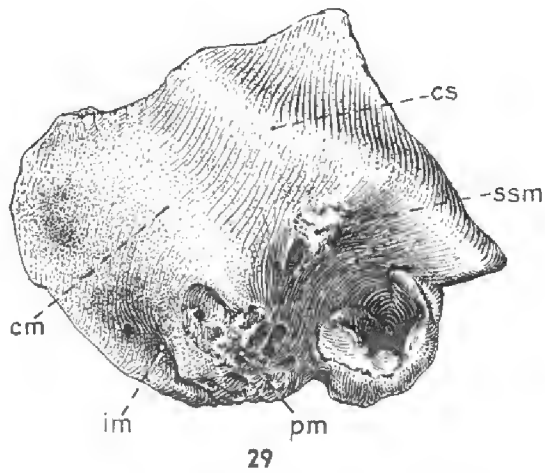
Fig. 35. *Sinanthropus* Skull VI—Skull VI Locus I; Fragments II and III (see Figure 32). Fragment in right orientation viewed from the left side. Drawing from the original. 1/1. Abbreviations: F III, fragment III; frc, depressed fracture; sa, artificial groove; ss, sutura squamosa; tbp, tuber parietale.

Fig. 36. *Sinanthropus* Skull VI—Skull VI Locus I; Fragment IV (see Figure 33). Drawing from the original. 1/1. Abbreviations: op, parietal bone; pz, processus zygomaticus ossis temporalis; ss, sutura squamosa.

Fig. 37. *Sinanthropus* Skull VII (Locus I). Fragment of the angulus mastoideus of the right parietal bone. Lateral view. Photograph from the original. 1/1.

Fig. 38. *Sinanthropus* Skull VII (Locus I). Lateral view. Drawing from the original (see Figure 37). 1/1. Abbreviations: sl, sutura lambdoidea; spm, sutura parietomastoidea; ss, sutura squamosa; tb, torus angularis ossis parietalis.

Fig. 39. *Sinanthropus* Skull VII (Locus I). The fragment depicted in Figures 37 and 38 viewed from behind. Drawing from the original. 1/1. Abbreviations: sl, sutura lambdoidea; tp, torus angularis.

Fig. 40. *Sinanthropus* Skull VII (Locus I). The fragment depicted in Figures 37 and 38 viewed from below. Drawing from the original. 1/1. Abbreviations: lt, linea temporalis; tp, torus angularis.
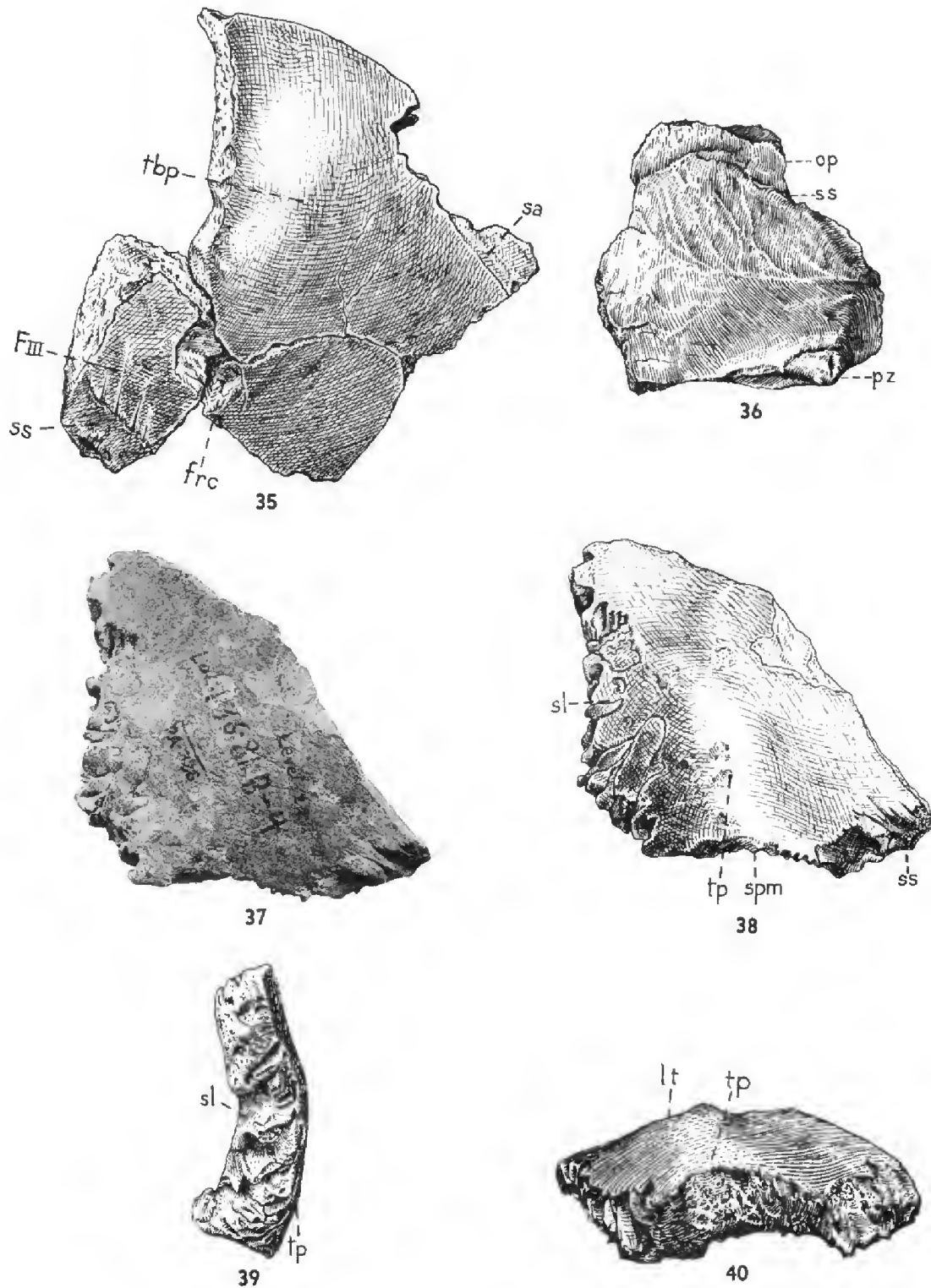
FIG. 41. *Sinanthropus* Skull VIII (Locus J). Fragment of an infantile occipital bone (central portion). Viewed from behind. Photograph from the original. 1/1.

FIG. 42. *Sinanthropus* Skull VIII (Locus J). Fragment of an infantile occipital bone (central portion). Cerebral side. Photograph from the original. 1/1.

FIG. 43. *Sinanthropus* Skull VIII (Locus J). Drawing from the original (see Figure 41). 1/1. Abbreviations: coe, crista occipitalis externa; st, sulcus supratoralis; t, torus occipitalis.

FIG. 44. *Sinanthropus* Skull VIII (Locus J). Drawing from the original (see Figure 42). 1/1. Abbreviations: ec, eminentia cruciata; fc, fossa cerebralis; sus, sulcus sagittalis.

FIG. 45. *Sinanthropus* Skull VIII (Locus J). Fragment viewed from the right side and behind. Drawing from the original. 1/1. Abbreviations: st, sulcus supratoralis; t, torus occipitalis.

FIG. 46. *Sinanthropus* Skull IX (Locus J). Fragment of the left moiety of a frontal squama. Lateral view. Photograph from the original. 1/1. Abbreviations: lti, linea temporalis inferior; lts, linea temporalis superior.

FIG. 47. *Sinanthropus* Skull IX (Locus J). Drawing of the fragment (see Figure 46) viewed from the lateral side. 1/1. Abbreviations: lti, linea temporalis inferior; lts, linea temporalis superior; pz, processus frontozygomaticus (broken off); sc, sutura coronalis; ssf, sutura sphenofrontalis.

FIG. 48. *Sinanthropus* Skull IX (Locus J). Fragment viewed from in front. Drawing from the original. 1/1. Abbreviations: fo, facies orbitalis; lti, linea temporalis inferior; lts, linea temporalis superior; pz, processus frontozygomaticus.
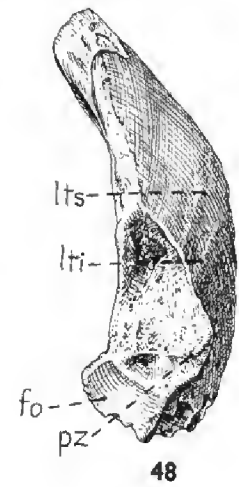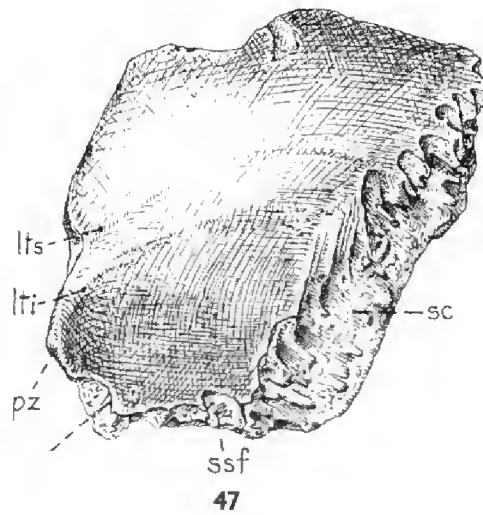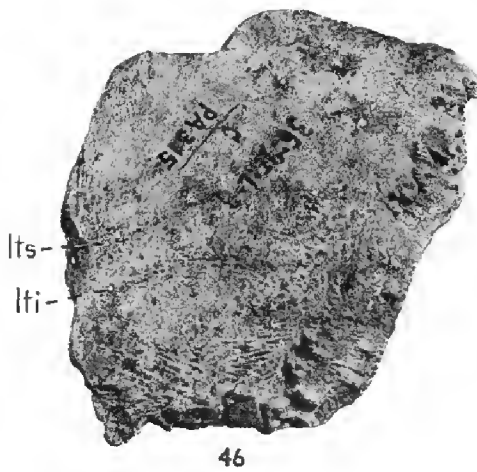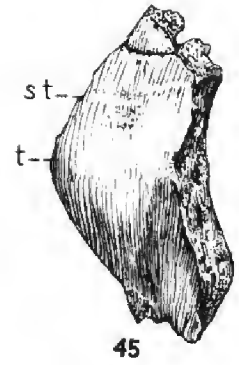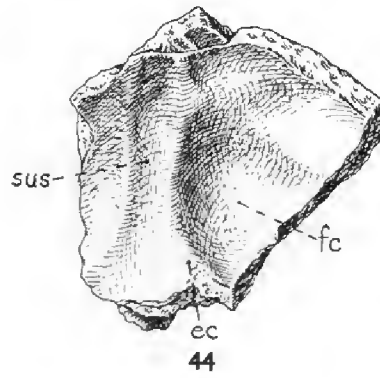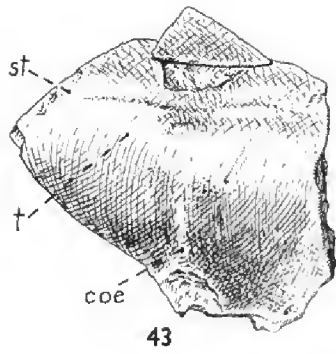
FIG. 49. *Sinanthropus* Skull X—Skull I Locus L.   Norma lateralis sinistra.   Photograph from the original.   1/2.

FIG. 50. *Sinanthropus* Skull X—Skull I Locus L.   Norma lateralis dextra.   Photograph from the original.   1/2.

FIG. 51. *Sinanthropus* Skull X—Skull I Locus L.   Norma frontalis.   Photograph from the original.   1/2.

FIG. 52. *Sinanthropus* Skull X—Skull I Locus L.   Norma occipitalis.   Photograph from the original.   1/2.
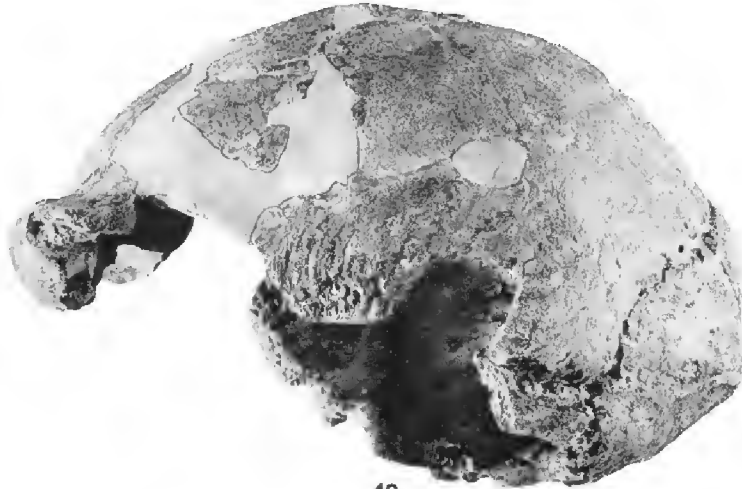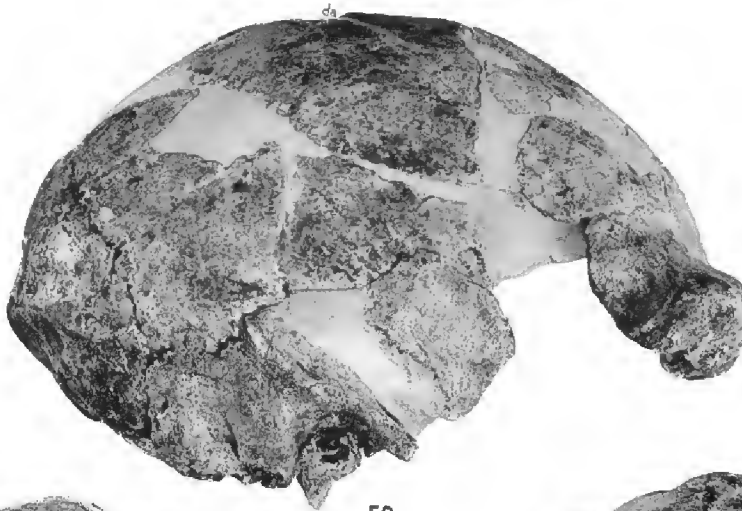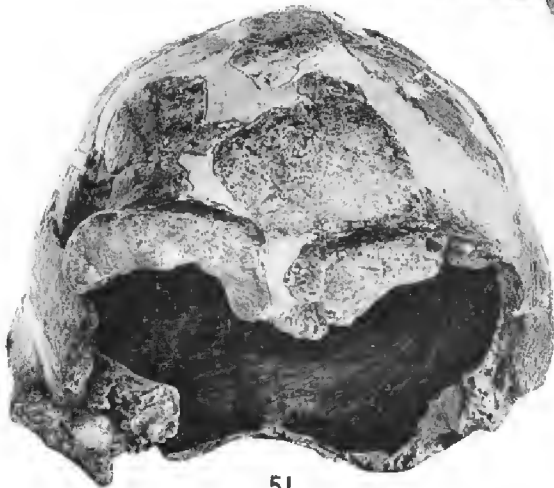
Fɪɢ. 53. *Sinanthropus* Skull X—Skull I Locus L.   Norma verticalis.   Photograph from the original.   1/2.

Fɪɢ. 54. *Sinanthropus* Skull X—Skull I Locus L.   Norma basalis.   Photograph from the original.   1/2.

Fɪɢ. 57. *Sinanthropus* Skull X—Skull I Locus L.   Norma frontalis.   Drawing from the original (see Figure 51). 1/1.   Abbreviations: csg, crista sagittalis; da, artificial depression; iso, incisura supraorbitalis; lt, linea temporalis; pso, processus supraorbitalis; suf, sutura nasofrontalis.

Fɪɢ. 55. See Plate XVI.

Fɪɢ. 56. See Plate XVII.
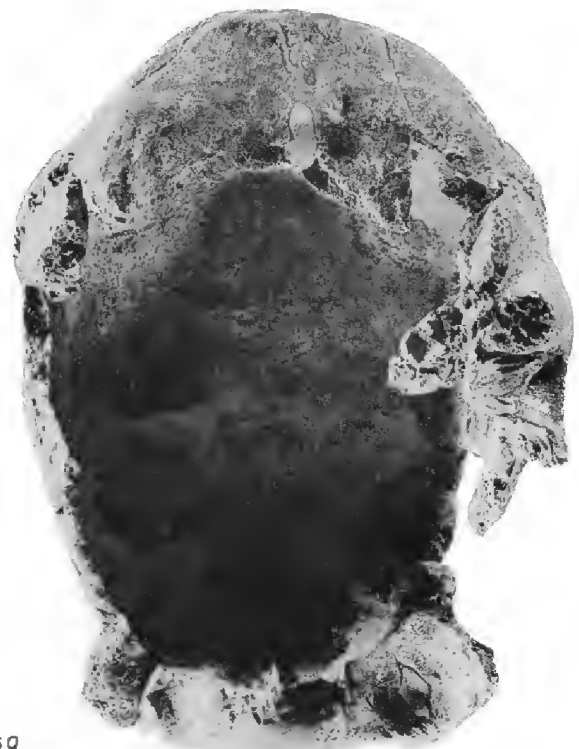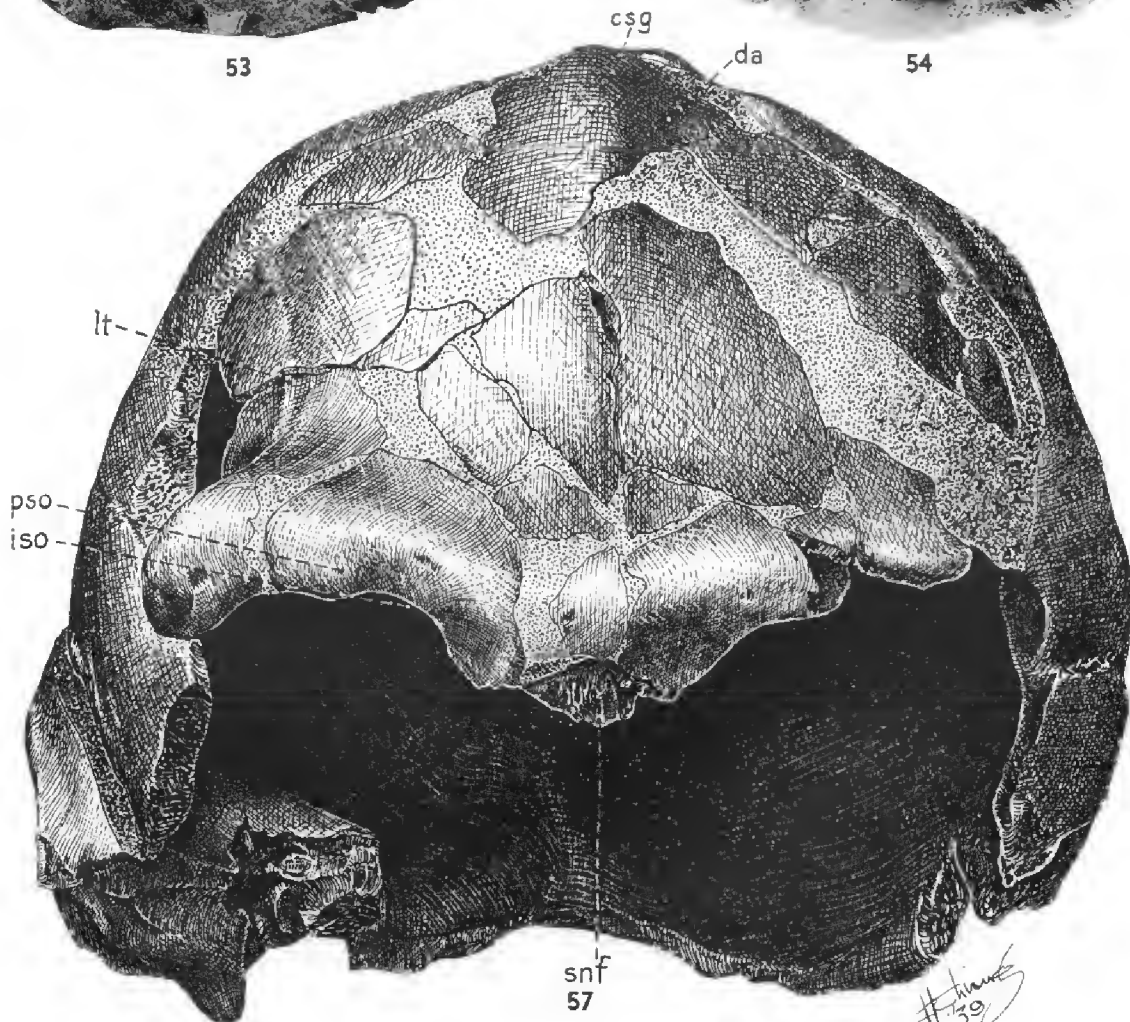
Fig. 55. *Sinanthropus* Skull X—Skull I Locus L. Norma lateralis sinistra. Drawing from the original (see Figure 49). 1/1. Abbreviations: da, artificial depression; pma, pars mastoidea ossis temporalis; ps, pars squamosa ossis temporalis; sc, sutura coronalis; st, sulcus supratoralis; t, torus occipitalis; tp, torus angularis ossis parietalis.
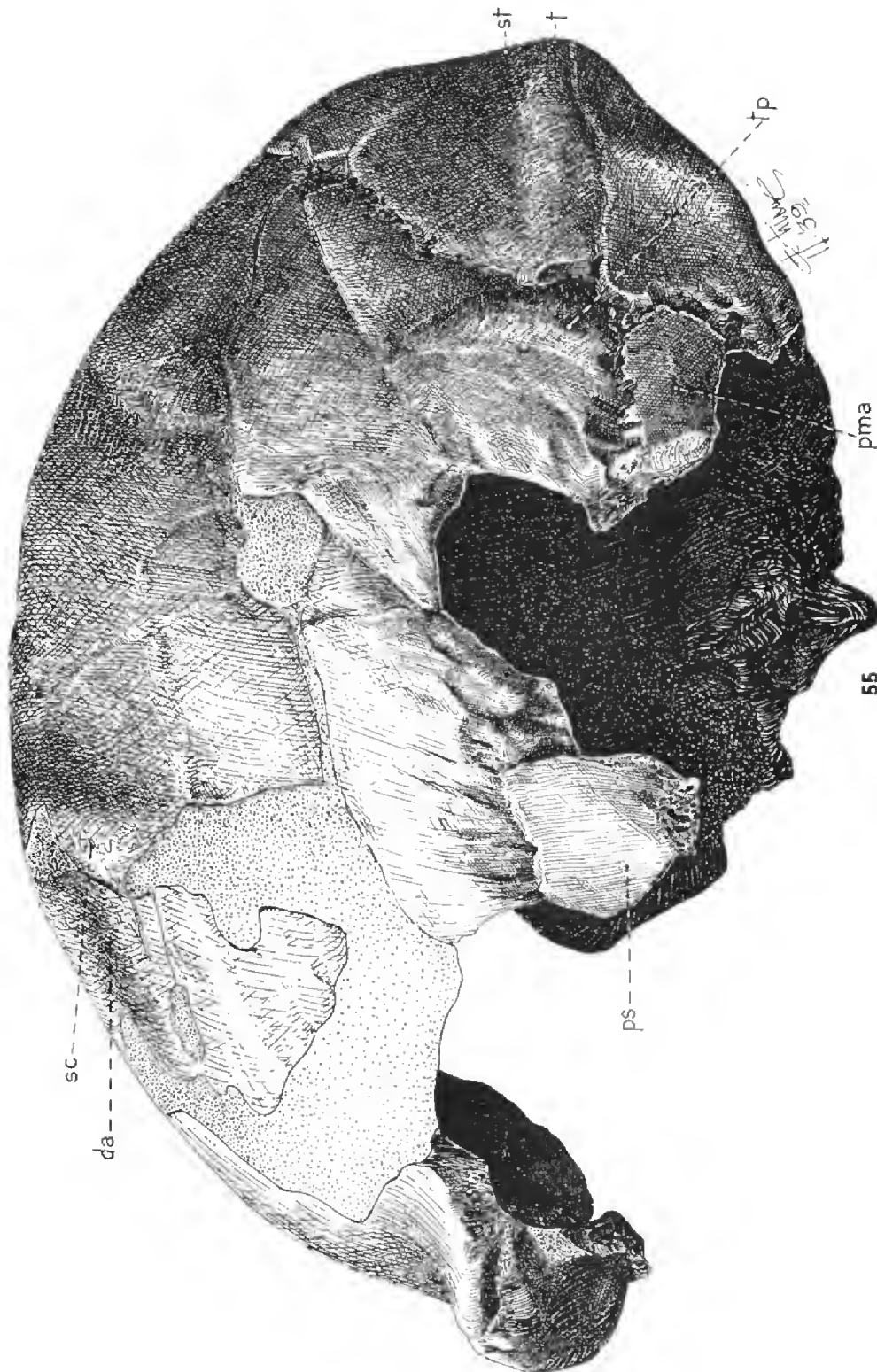
FIG. 56. *Sinanthropus* Skull X—Skull I Locus L. Norma lateralis dextra. Drawing from the original (see Figure 50). 1/1. Abbreviations: cm, crista mastoidea; da, artificial depression; im, incisura mastoidea; lt, linea temporalis; pm, processus mastoideus; sm, sutura mendosa; t, torus occipitalis; tp, torus angularis ossis parietalis.
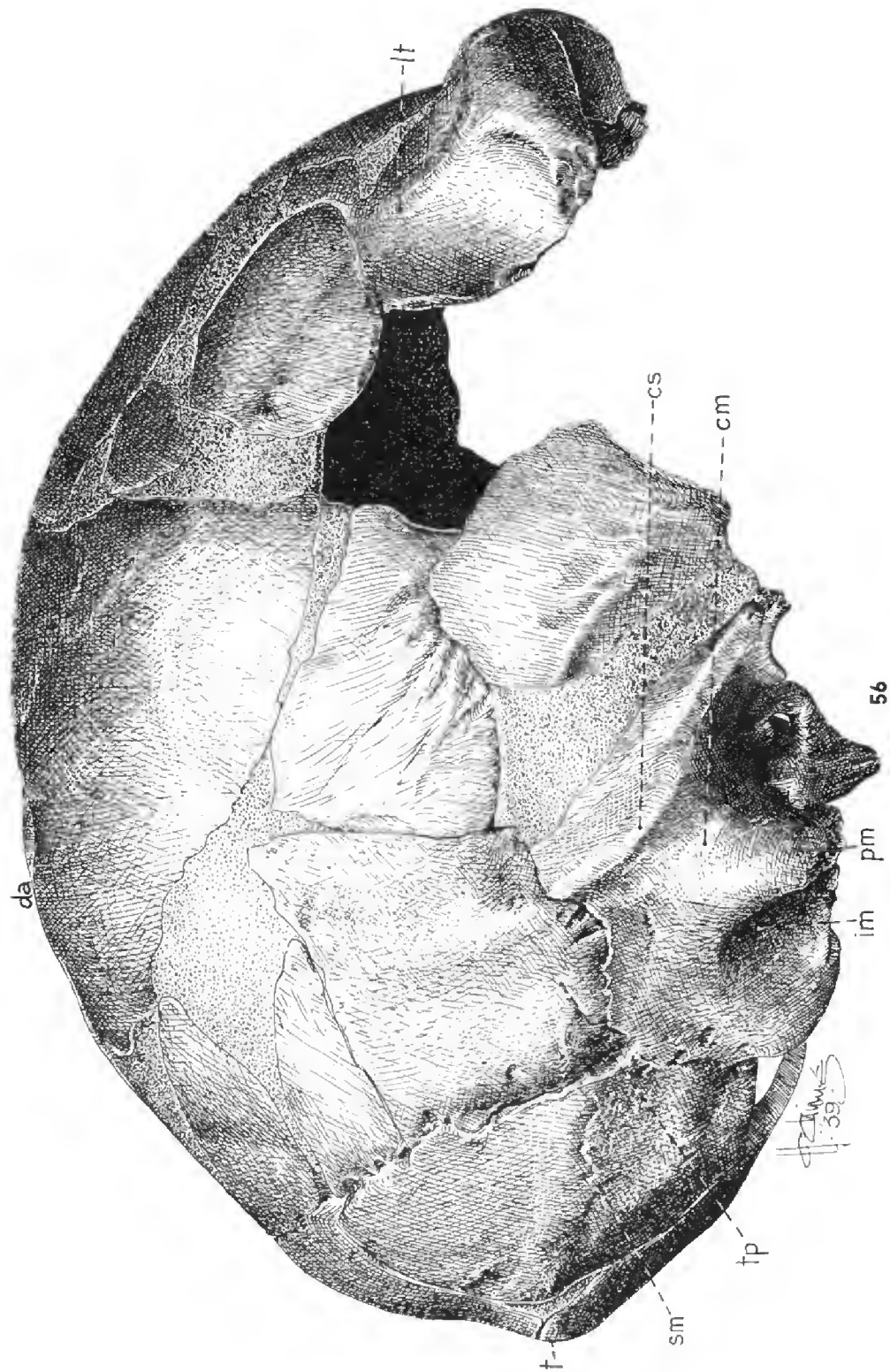
FIG. 58. *Sinanthropus* Skull X—Skull I Locus L. Norma occipitalis. Drawing from the original (see Figure 52). 1/1. Abbreviations: cs, crista supramastoidea; csg, crista sagittalis; fma, foramen mastoideum; im, incisura mastoidea; lt, linea temporalis; sm, sutura mendosa; t, torus occipitalis; tp, torus angularis ossis parietalis.

FIG. 57. See Plate XV.

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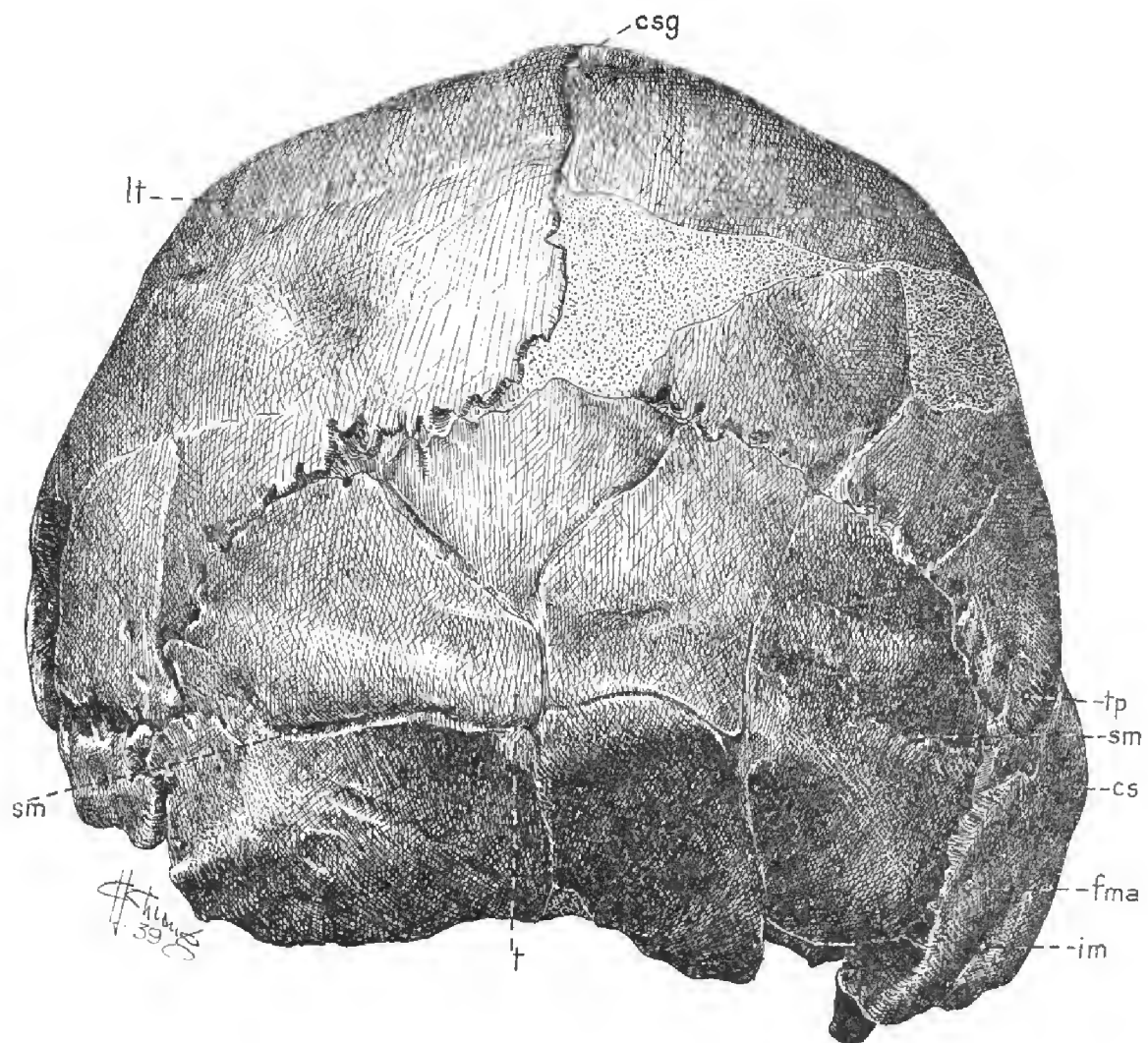
FIG. 59. *Sinanthropus* Skull X—Skull I Locus L. Norma verticalis. Drawing from the original (see Figure 53). 1/1. Abbreviations: csg, crista sagittalis; da,' artificial depression; tp, torus angularis ossis parietalis.

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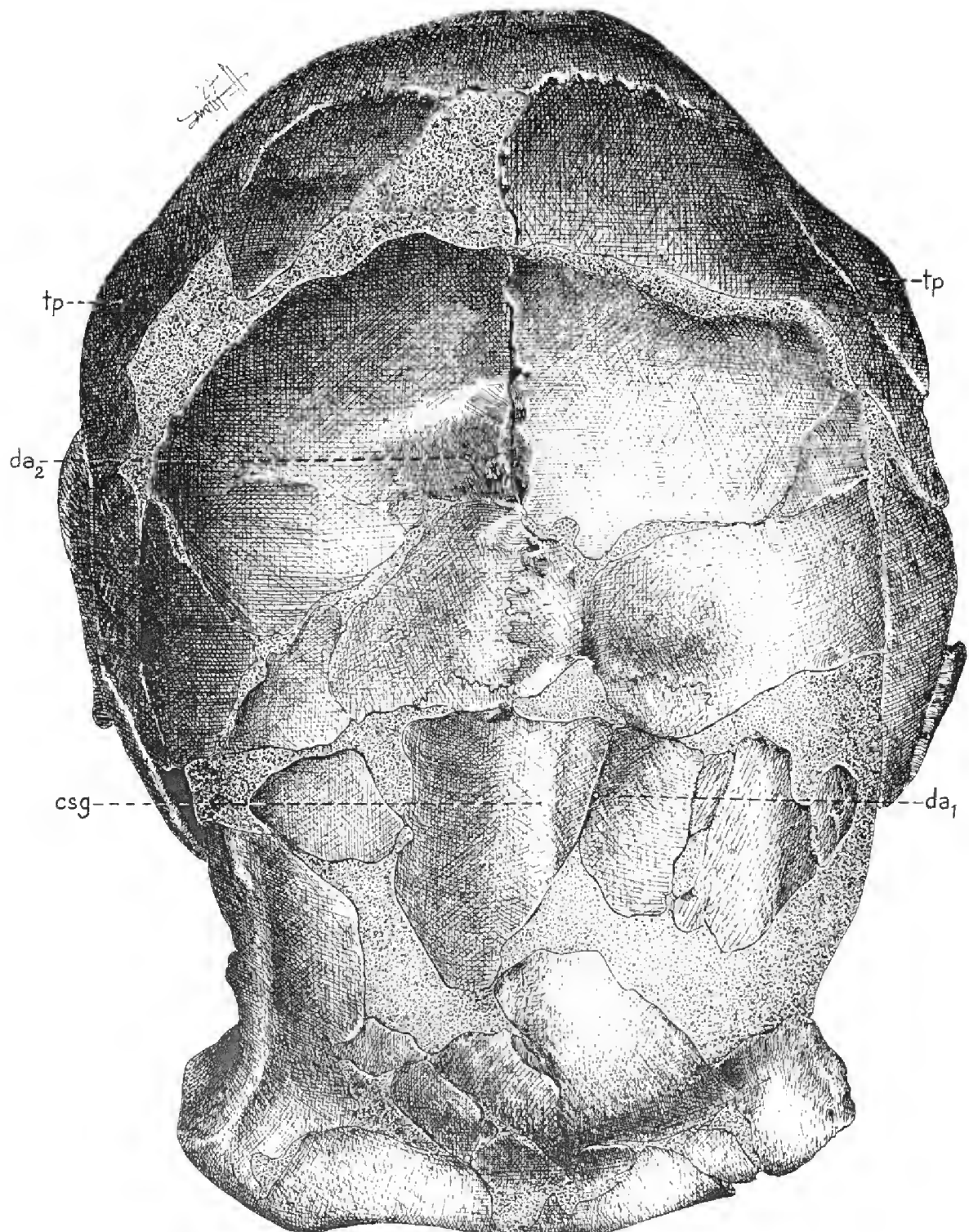
FIG. 60. *Sinanthropus* Skull X—Skull I Locus L. Norma basalis. Drawing from the original (see Figure 54). 1/1. Abbreviations: iso, incisura supraorbitalis; sf, sinus frontalis; sfe, sutura frontoethmoidalis; snf, sutura nasofrontalis; tp, torus angularis ossis parietalis.

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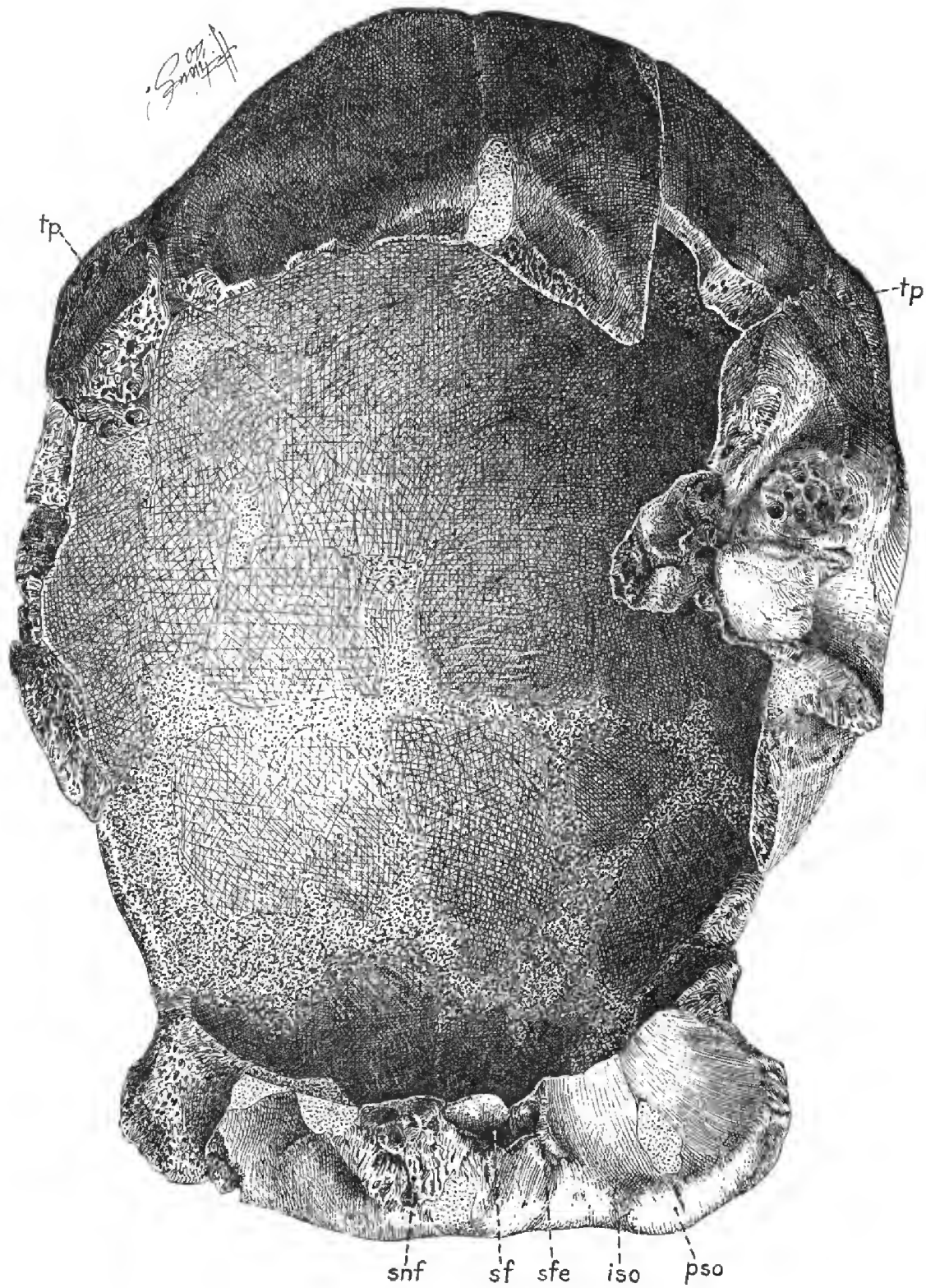
FIG. 61. *Sinanthropus* Skull XI—Skull II Locus L. Norma lateralis sinistra. Photograph from the original. 1/2.

FIG. 62. *Sinanthropus* Skull XI—Skull II Locus L. Norma lateralis dextra. Photograph from the original. 1/2.

FIG. 63. *Sinanthropus* Skull XI—Skull II Locus L. Norma frontalis. Photograph from the original. 1/2.

FIG. 64. *Sinanthropus* Skull XI—Skull II Locus L. Norma occipitalis. Photograph from the original. 1/2.
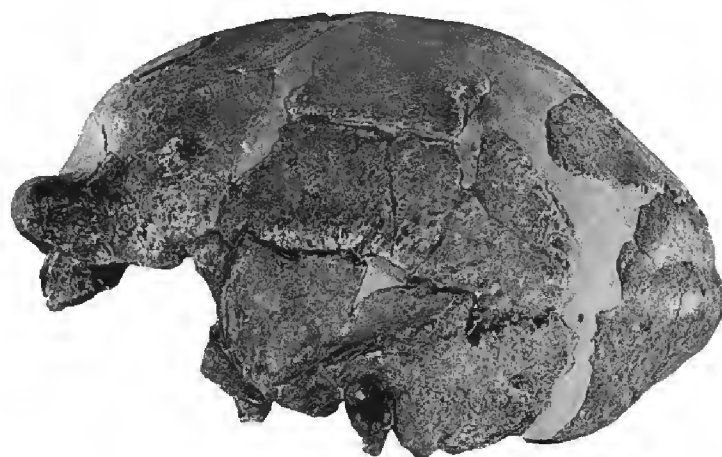
Fig. 65. *Sinanthropus* Skull XI—Skull II Locus L. Norma verticalis. Photograph from the original. 1/2.

Fig. 66. *Sinanthropus* Skull XI—Skull II Locus L. Norma basalis. Photograph from the original. 1/2.

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FIG. 67. *Sinanthropus* Skull XI—Skull II Locus L.   Norma lateralis sinistra.   Drawing from the original (see Figure 61).   1/1.   Abbreviations: al, ala magna ossis sphenoidalis; da, artificial depression; fma, foramen mastoideum; lt, linea temporalis; tp, torus angularis ossis parietalis.
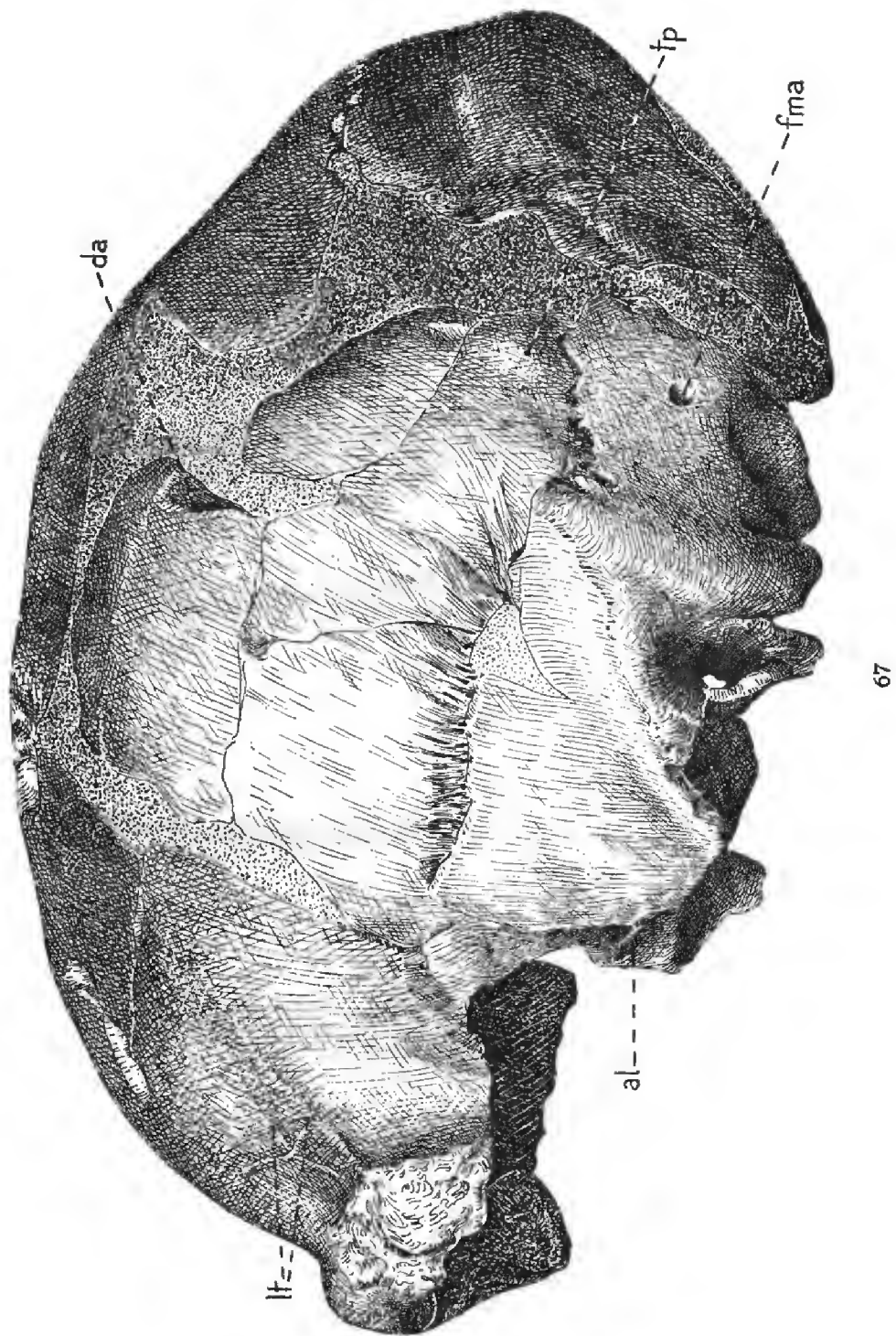
Fig. 68. *Sinanthropus* Skull XI—Skull II Locus L. Norma lateralis dextra. Drawing from the original (see Figure 62). 1/1. Abbreviations: da, artificial depression; ij, injury; lt, linea temporalis; tp, torus angularis ossis parietalis.
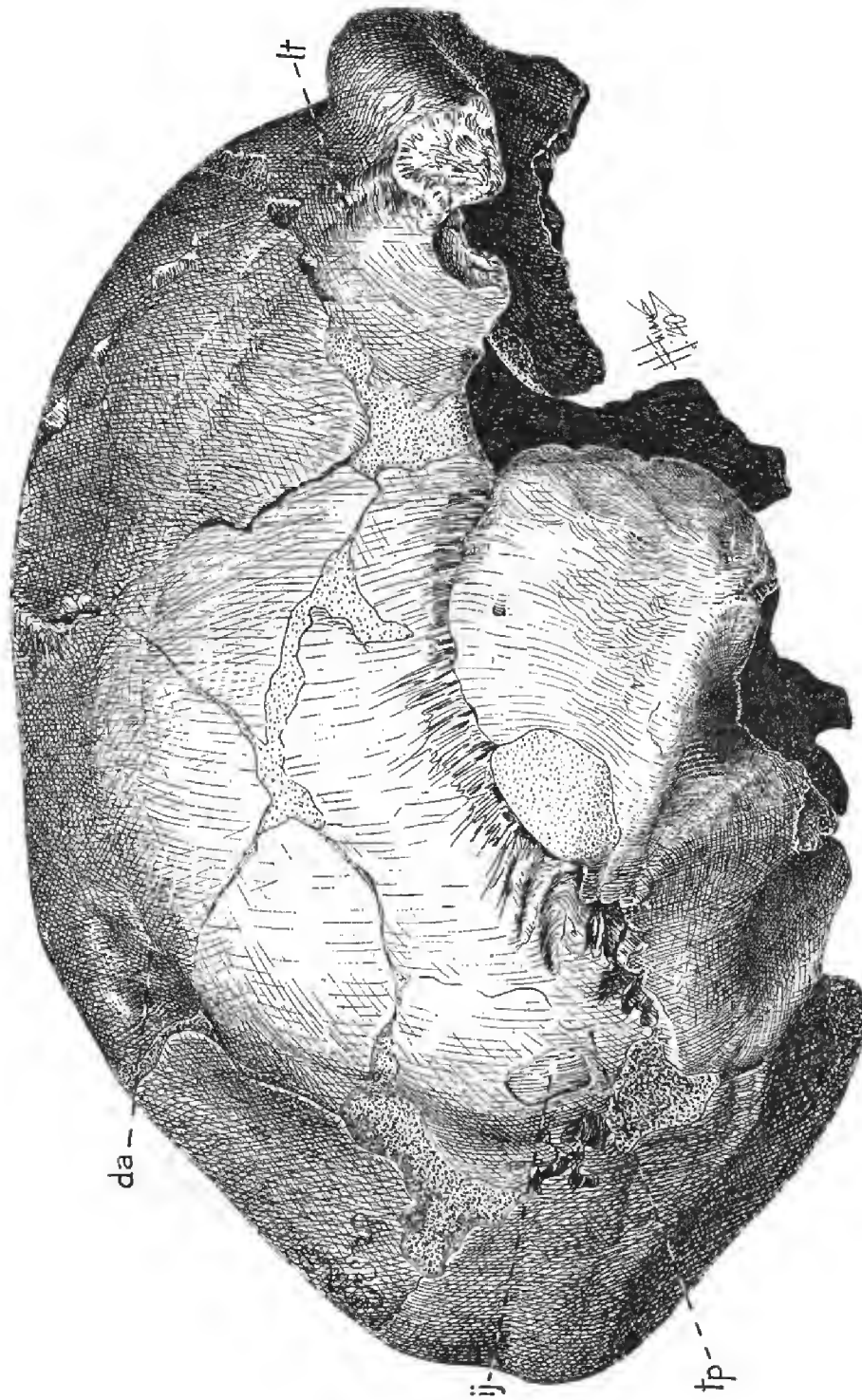
Fɪɢ. 69. *Sinanthropus* Skull XI—Skull II Locus L.   Norma frontalis.   Drawing from the original (see Figure 63).   1/1.   Abbreviations: al, ala magna ossis sphenoidalis; cs, crista supramastoidea; csg, crista sagittalis; pso, processus supraorbitalis; smt, sutura metopica.

Fɪɢ. 70. *Sinanthropus* Skull XI—Skull II Locus L.   Norma occipitalis.   Drawing from the original (see Figure 64).   1/1.   Abbreviations: csg, crista sagittalis; da, artificial depression; st, sulcus supratoralis; sto, sutura transversa occipitalis; t, torus occipitalis; tp, torus angularis ossis parietalis.
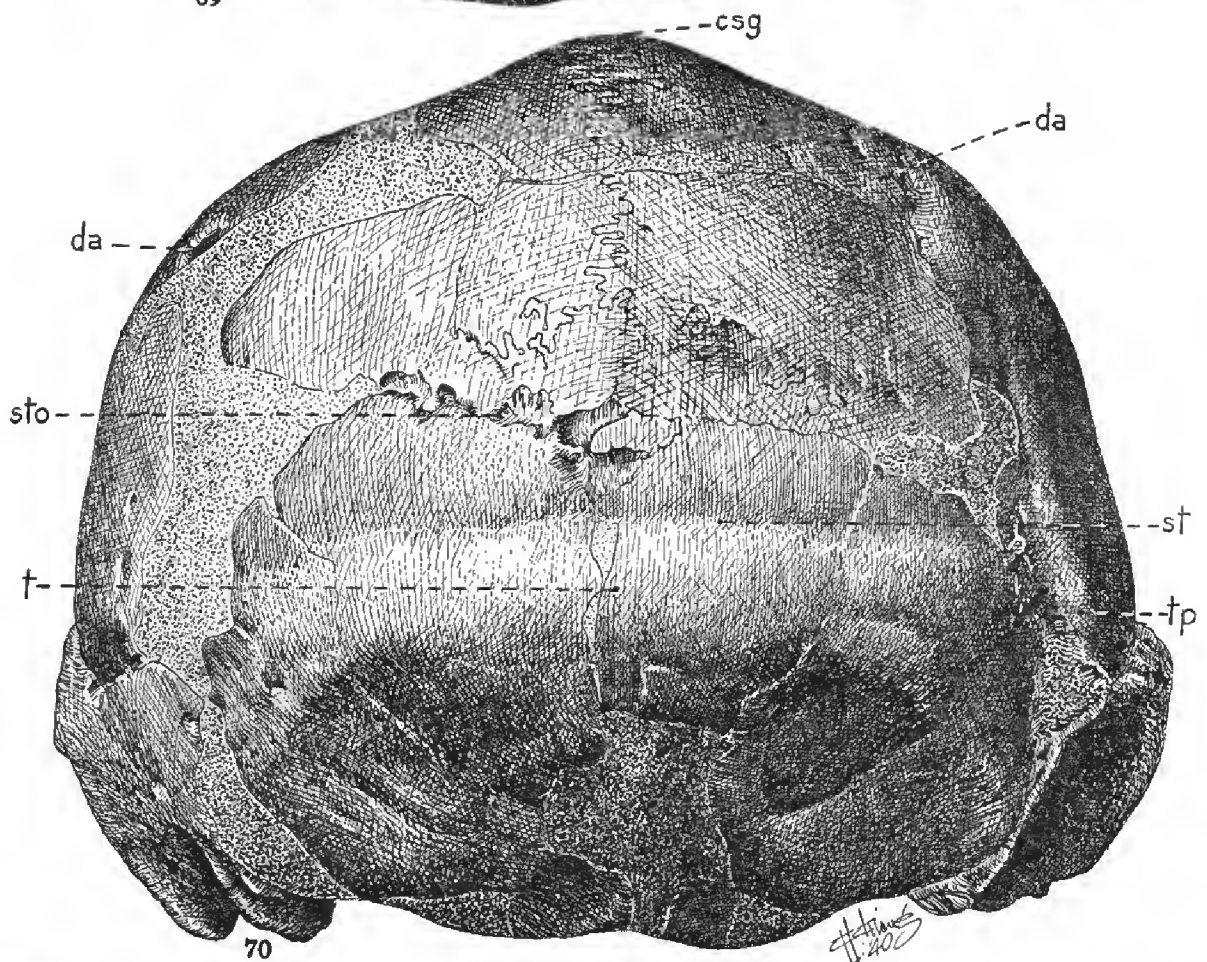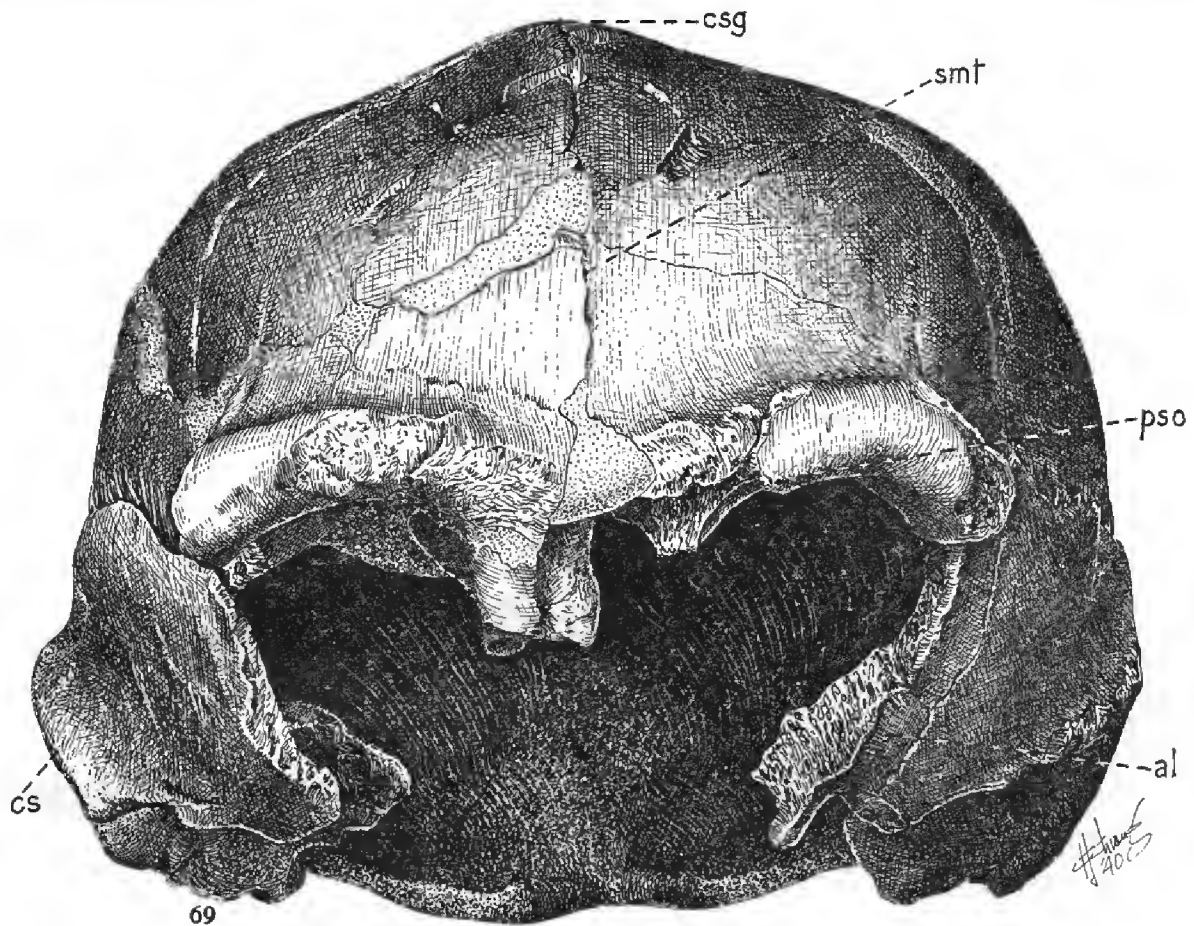
Fig. 71. *Sinanthropus* Skull XI—Skull II Locus L. Norma verticalis. Drawing from the original (see Figure 65). 1/1. Abbreviations: da, artificial depression; smt, sutura metopica; sto, sutura transversa occipitalis; tp, torus angularis ossis parietalis.

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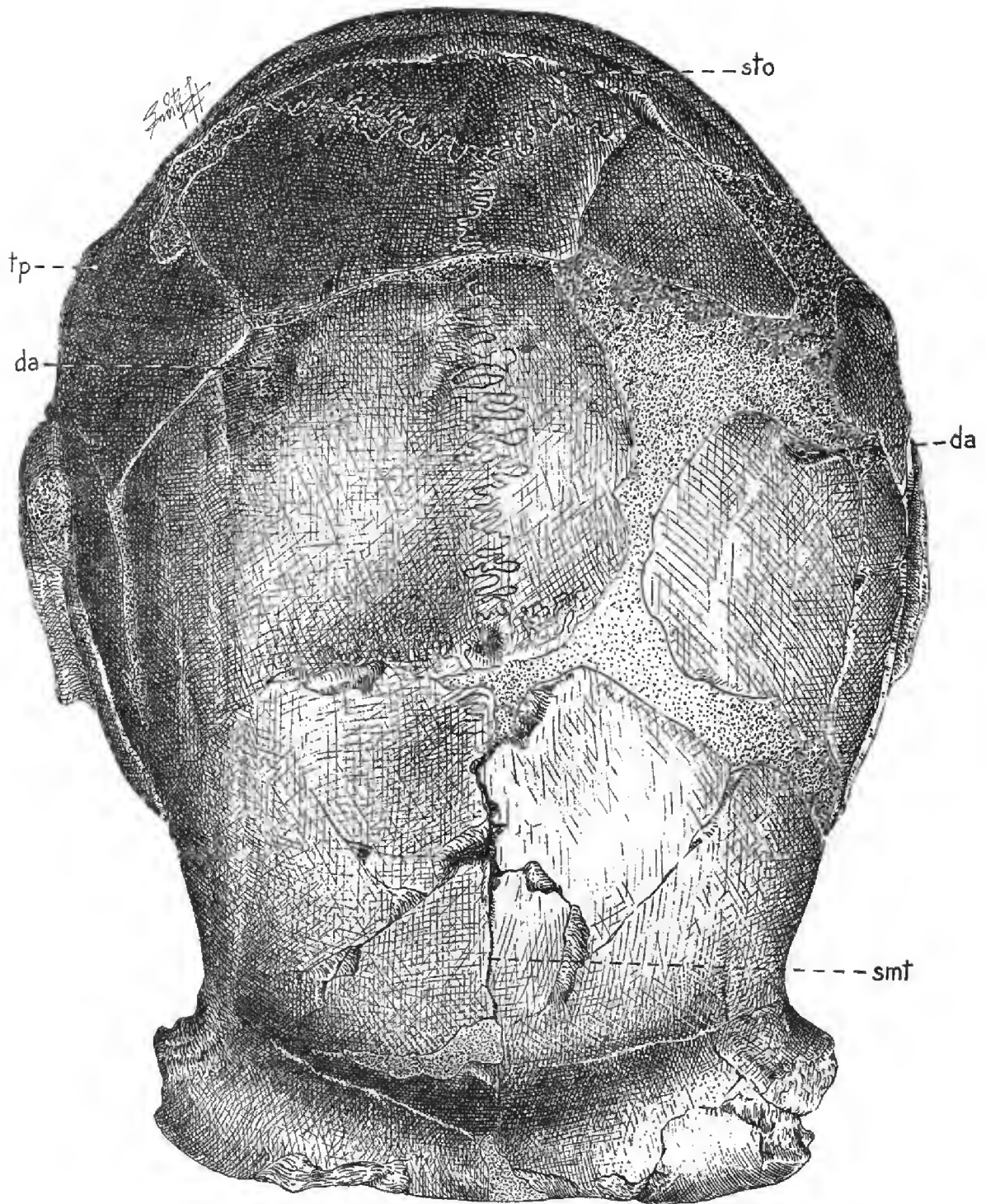
Fig. 72. *Sinanthropus* Skull XI—Skull II Locus L. Norma basalis. Drawing from the original (see Figure 66). 1/1. Abbreviations: bpp, basis processus pterygoidei; ce, cellula ethmoidalis; fmg, foramen occipitale; for, foramen ovale; lp, lamina perpendicularis; sf, sinus frontalis; sfe, sutura frontoethmoidalis; sss, sutura sphenosquamosa; tp, torus angularis ossis parietalis.
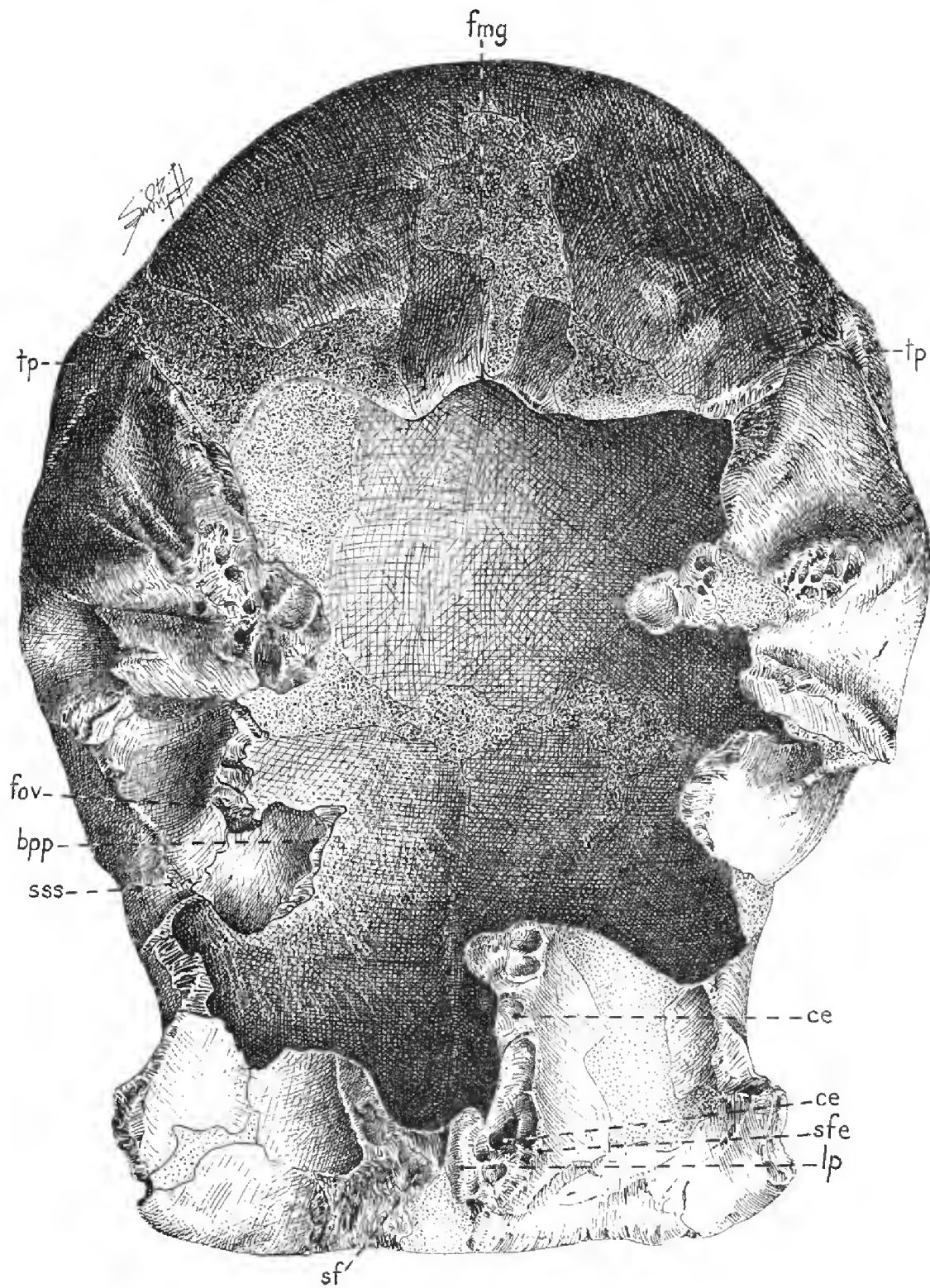
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Fig. 77. *Sinanthropus* Skull XII—Skull III Locus L. Norma verticalis. Photograph from the original. 1/2.

Fig. 78. *Sinanthropus* Skull XII—Skull III Locus L. Norma basalis. Photograph from the original. 1/2.

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Fig. 79. *Sinanthropus* Skull XII—Skull III Locus L. Norma lateralis sinistra. Drawing from the original (see Figure 73). 1/1. Abbreviations: al, ala magna ossis sphenoidalis; foi, fissura orbitalis inferior; ft, fossa temporalis ossis zygomatici; lt, linea temporalis; oa, os interparietale; sca, scar; snf, sutura nasofrontalis; st, sulcus supratoralis; szf, sutura zygomaticofrontalis; t, torus occipitalis; tp, torus angularis ossis parietalis.
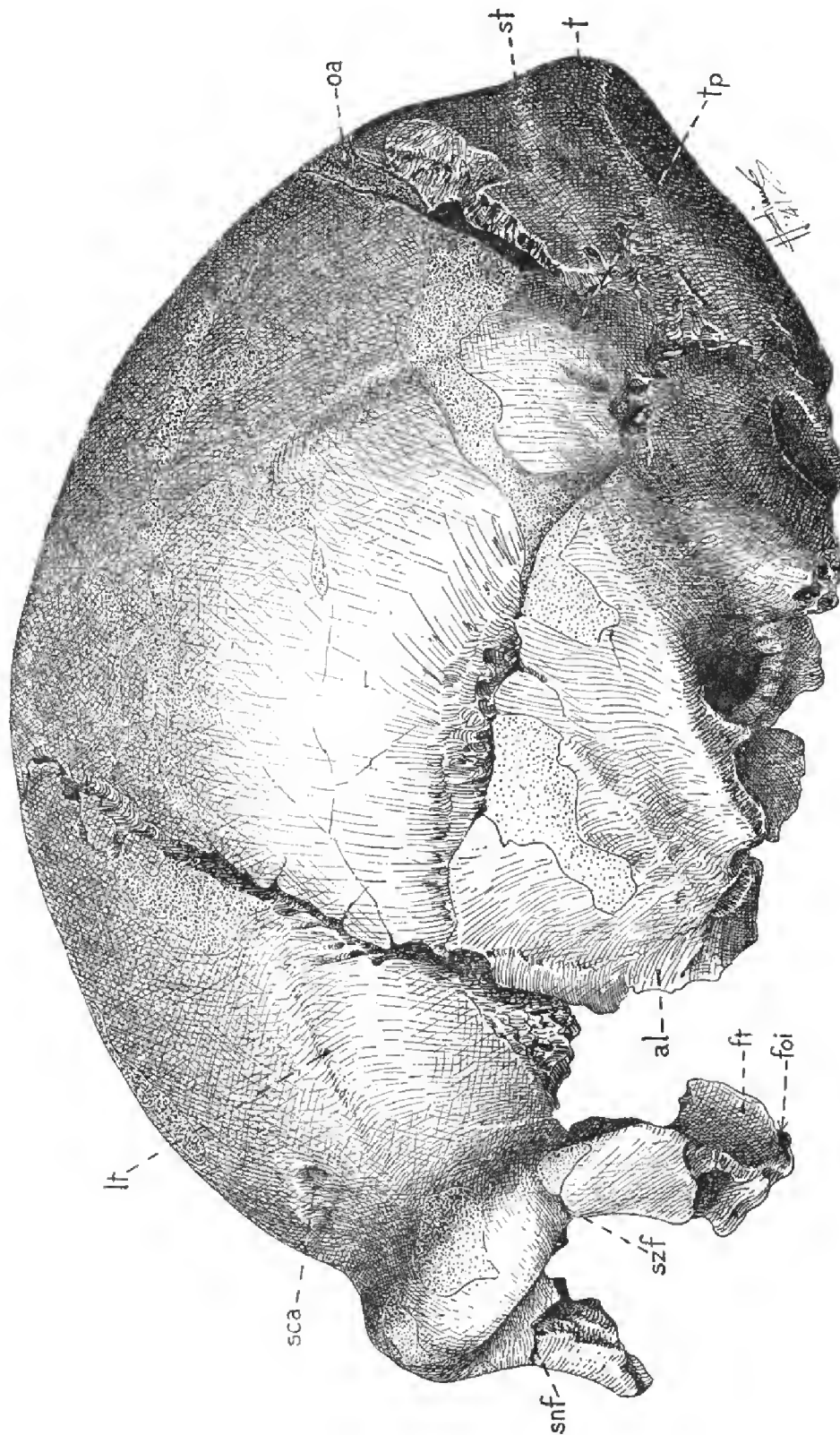
Fig. 80. *Sinanthropus* Skull XII—Skull III Locus L.   Norma lateralis dextra.   Drawing from the original (see Figure 74).   1/1.   Abbreviations: da, artificial depression; fo, facies orbitalis ossis zygomatici; fzo, foramen zygomatico-orbitale; ls, linea nuchae superior; lt, linea temporalis; oa, os interparietale; sma, sinus maxillaris; ssf, sutura sphenofrontalis; st, sulcus supratoralis; szf, sutura zygomaticofrontalis; t, torus occipitalis; tp, torus angularis ossis parietalis.
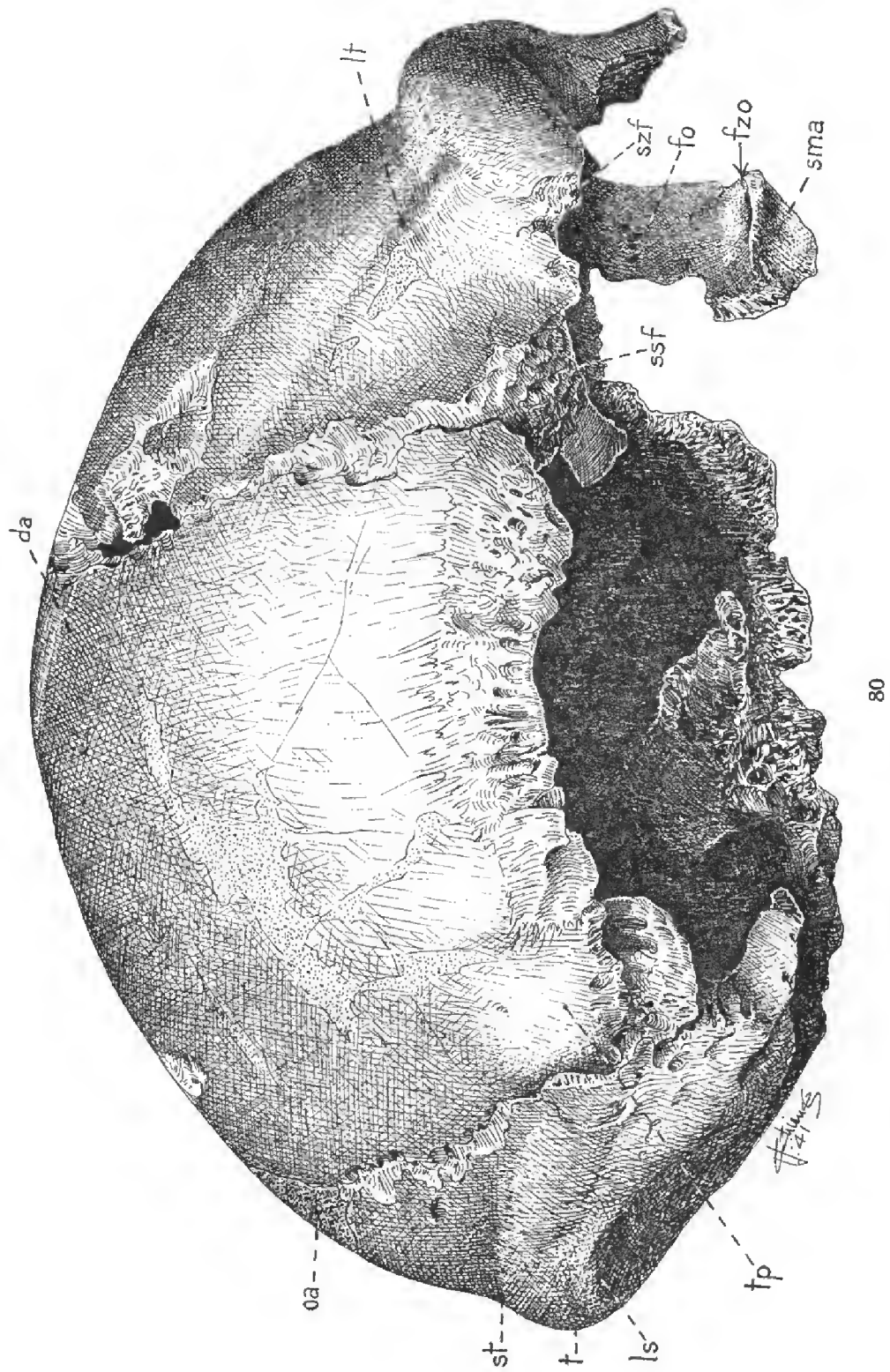
FIG. 81. *Sinanthropus* Skull XII—Skull III Locus L. Norma frontalis. Drawing from the original (see Figure 75). 1/1. Abbreviations: czf, canalis zygomaticofrontalis; csg, crista sagittalis; iso, incisura supraorbitalis; lt, linea temporalis; pso, processus supraorbitalis; sca, scar; sma, sinus maxillaris; snm, sutura nasomaxillaris; snf, sutura nasofrontalis; szf, sutura zygomaticofrontalis; tbp, tuber parietale.

FIG. 82. *Sinanthropus* Skull XII—Skull III Locus L. Norma occipitalis. Drawing from the original (see Figure 76). 1/1. Abbreviations: i, injury; ls, linea nuchae superior; oa, os interparietale; st, sulcus supratoralis; t, torus occipitalis; tp, torus angularis ossis parietalis.
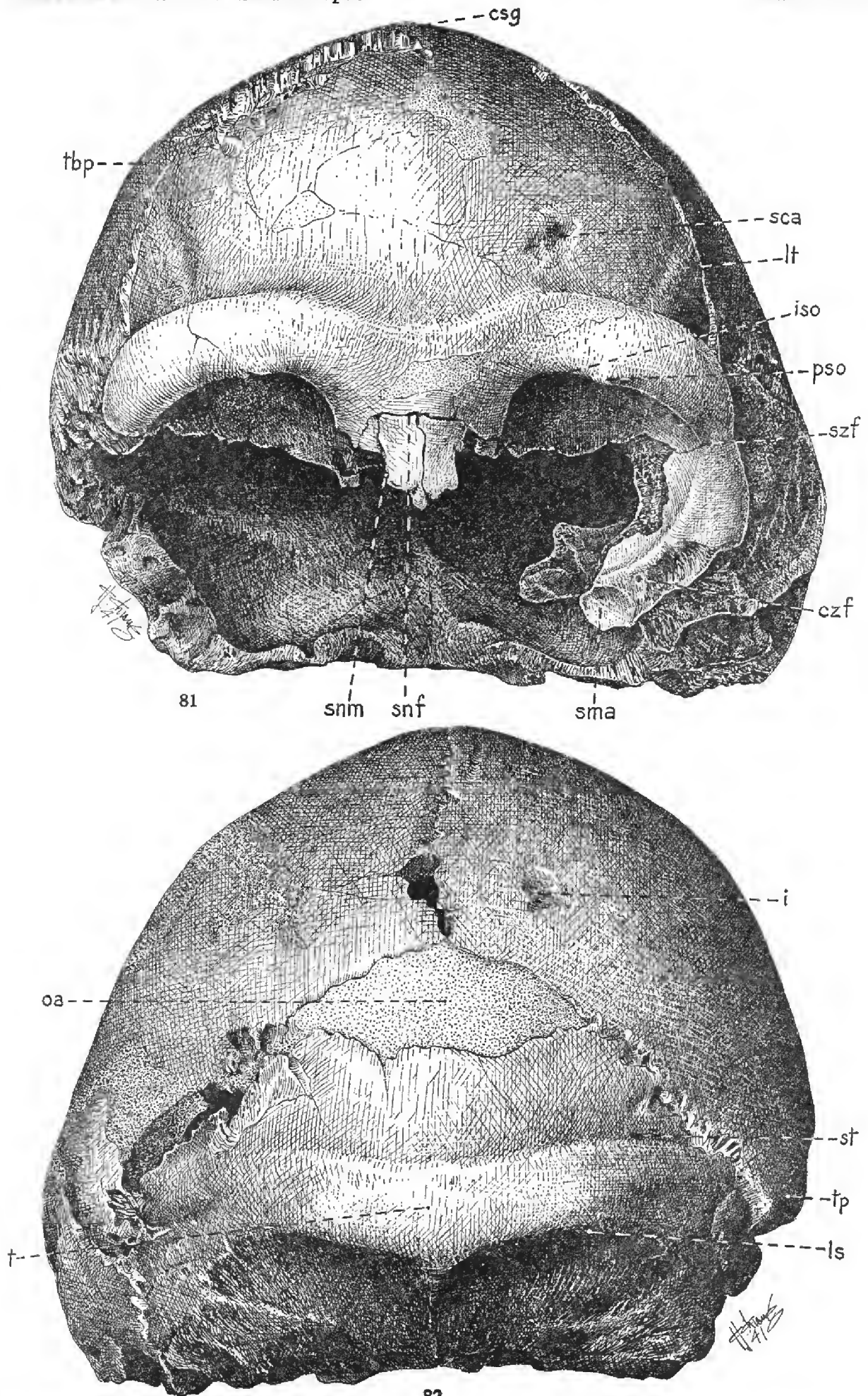
FIG. 83. *Sinanthropus* Skull XII—Skull III Locus L. Norma verticalis. Drawing from the original (see Figure 77). 1/1. Abbreviations: da, artificial depression; i, injury; oa, os interparietale; sca, scar; st, sulcus supratoralis; tp, torus angularis ossis parietalis.

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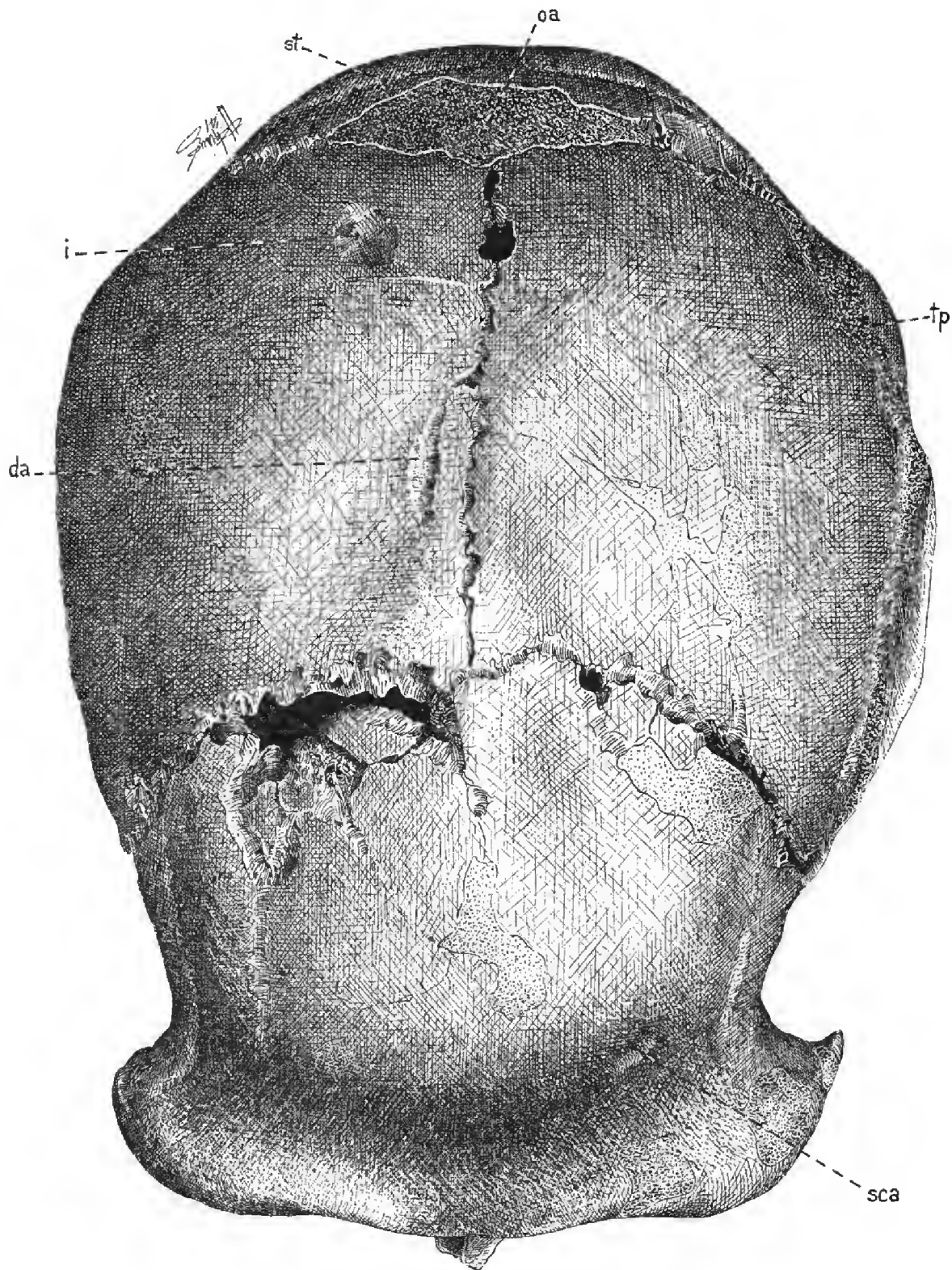
Fig. 84.   *Sinanthropus* Skull XII—Skull III Locus L.   Norma basalis.   Drawing from the original (see Figure 78).   1/1.   Abbreviations: al, ala magna ossis sphen.; bpp, basis proc. pteryg.; ce, cellula ethmoidalis; coe, crista occipitalis ext.; fm, fossa mandibularis; fmg, foramen occipitale; foi, fissura orbitalis inf.; fop, foramen opticum; fos, fissura orbitalis superior; ie, incisura ethmoidalis; iso, incisura supraorbitalis; lp, lamina perpendicularis; ls, linea nuchae superior; mn, meatus nasi; sf, sinus frontalis; sfe, sutura frontoethmoidalis; sma, sinus maxillaris; ssf, sutura sphenofrontalis; sss, sutura sphenosquamosa; szf, sutura zygomaticofrontalis; t, torus occipitalis; tg, tegmen pori acustici ext.; tp, torus angularis ossis parietalis.

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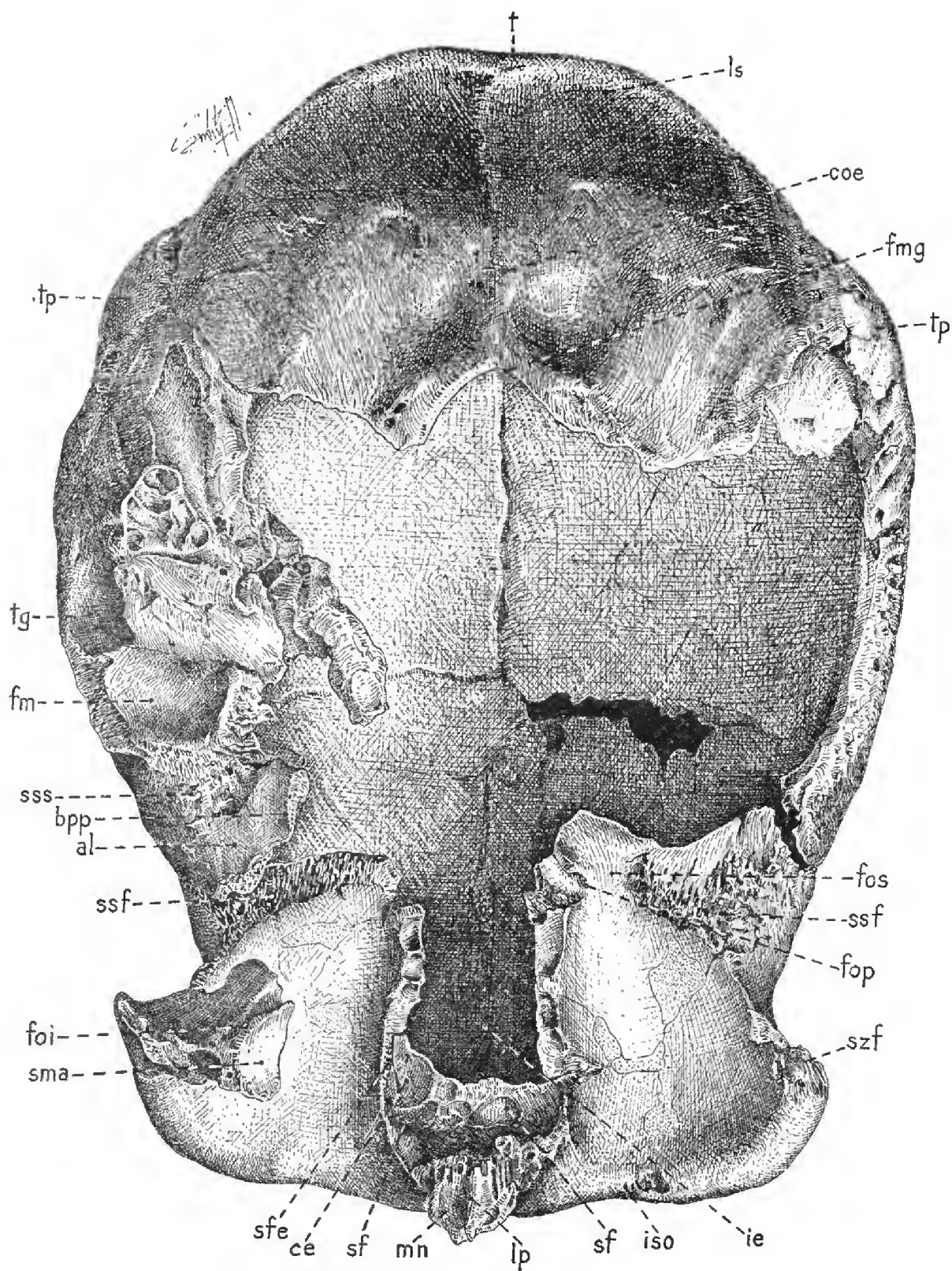
Fig. 85. Graphic reconstruction of the norma lateralis sinistra of *Sinanthropus* Skull V—Skull III Locus H (see Figure 21). Reconstructed contours – – –. 3/4. Abbreviation: FH, Frankfort Horizontal.

Fig. 86. Reconstruction of a female *Sinanthropus* skull on the basis of *Sinanthropus* Skull XI (see Figure 61), facial bones No. I–III (see Figures 135, 160, 148), and Mandible H I (see Weidenreich, 1936 b; Pl. VII, Figs. 1–5). Reconstructed with the kind assistance of Mrs. Lucille Swan. Norma lateralis sinistra. 1/2.

Fig. 87. Reconstruction of a female *Sinanthropus* skull (see Figure 86). Norma frontalis. 1/2.

Fig. 88. Reconstruction of a female *Sinanthropus* skull (see Figure 86). Norma occipitalis. 1/2.

FH

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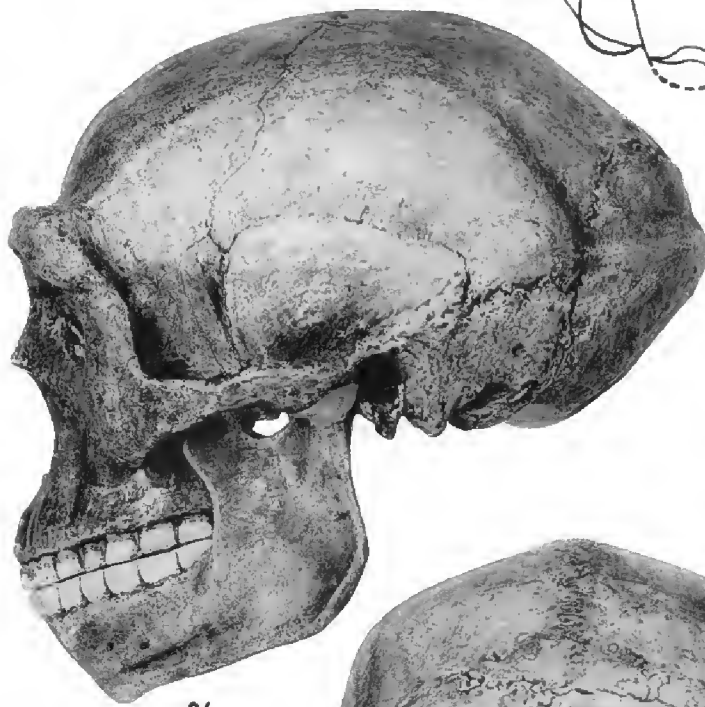
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FIG. 89. Reconstruction of a female *Sinanthropus* skull (see Figure 86).   Norma verticalis.   1/2.

FIG. 90. Separate frontal bone of *Sinanthropus* Skull XII (see Figures 75–77, and 81–83).   Viewed from in front and above.   Photograph from the original.   2/3.

FIG. 92. Separate frontal bone of *Sinanthropus* Skull XII.   Cerebral view.   Drawing from the original (see Figure 91).   1/1.   Abbreviations: ap, ala parva ossis sphenoid.; cf, crista frontalis; foi, fissura orbitalis inferior; fop, foramen opticum; lid, limen coronale; lp, lamina perpendicularis; pfs, processus frontosphenoidalis; pz, processus frontozygomaticus; ssf, sutura sphenofrontalis; szf, sutura zygomatico-frontalis.

FIG. 91. See Plate XXXVII.
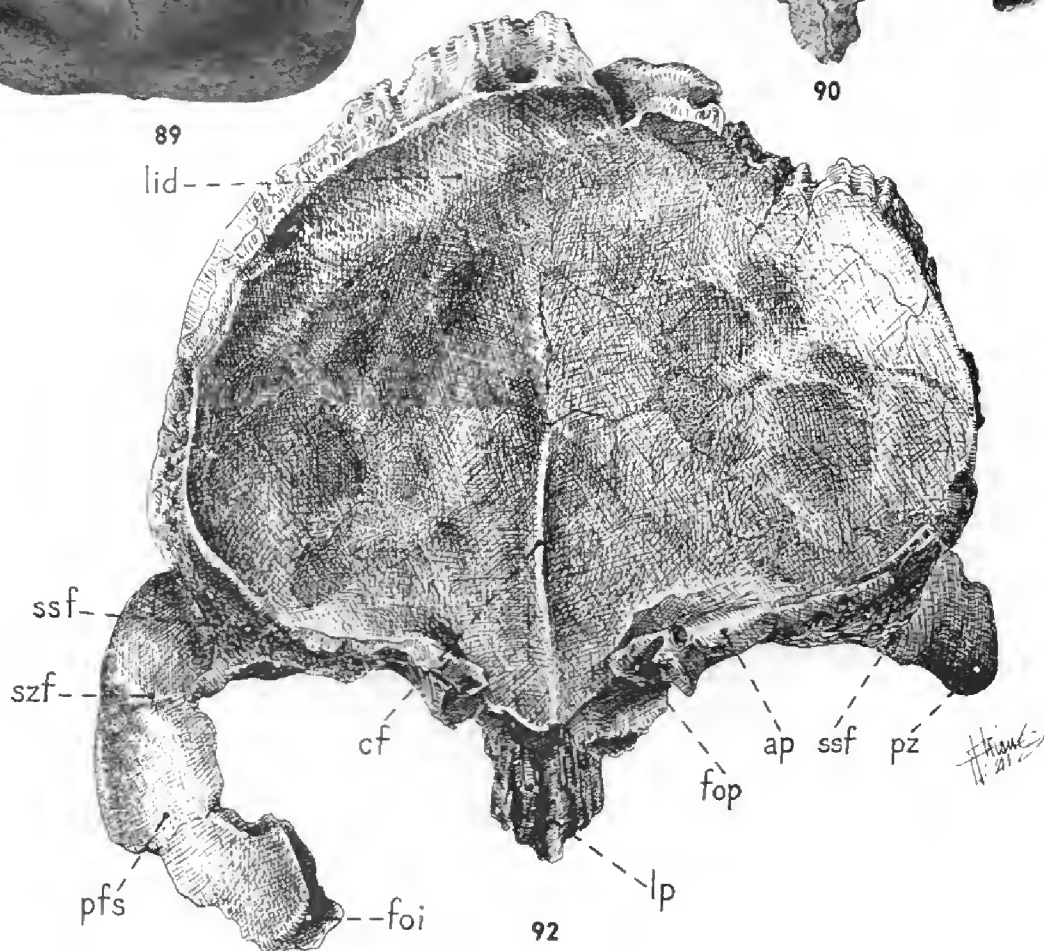
Fig. 91. Separate frontal bone of *Sinanthropus* Skull XII. Cerebral view. Photograph from the original. 2/3.

Fig. 93. Separate left parietal and temporal bones of *Sinanthropus* Skull XII. Lateral view. Photograph from the original. 2/3.

Fig. 94. Separate left parietal and temporal bones of *Sinanthropus* Skull XII. Cerebral side. Photograph from the original. 2/3.

Fig. 95. Separate left parietal and temporal bones of *Sinanthropus* Skull XII. Cerebral side. Drawing from the original. 1/1. Abbreviations: av, apertura ext. aquaeduct. vestib.; csy, crista sylvii; ea, eminentia arcuata; mai, meatus acusticus internus; sig, sulcus sigmoideus.

Fig. 96. Separate right parietal bone of *Sinanthropus* Skull XII. Lateral view. Photograph from the original. 2/3. Abbreviation: tp, torus angularis.

Fig. 92. See Plate XXXVI.
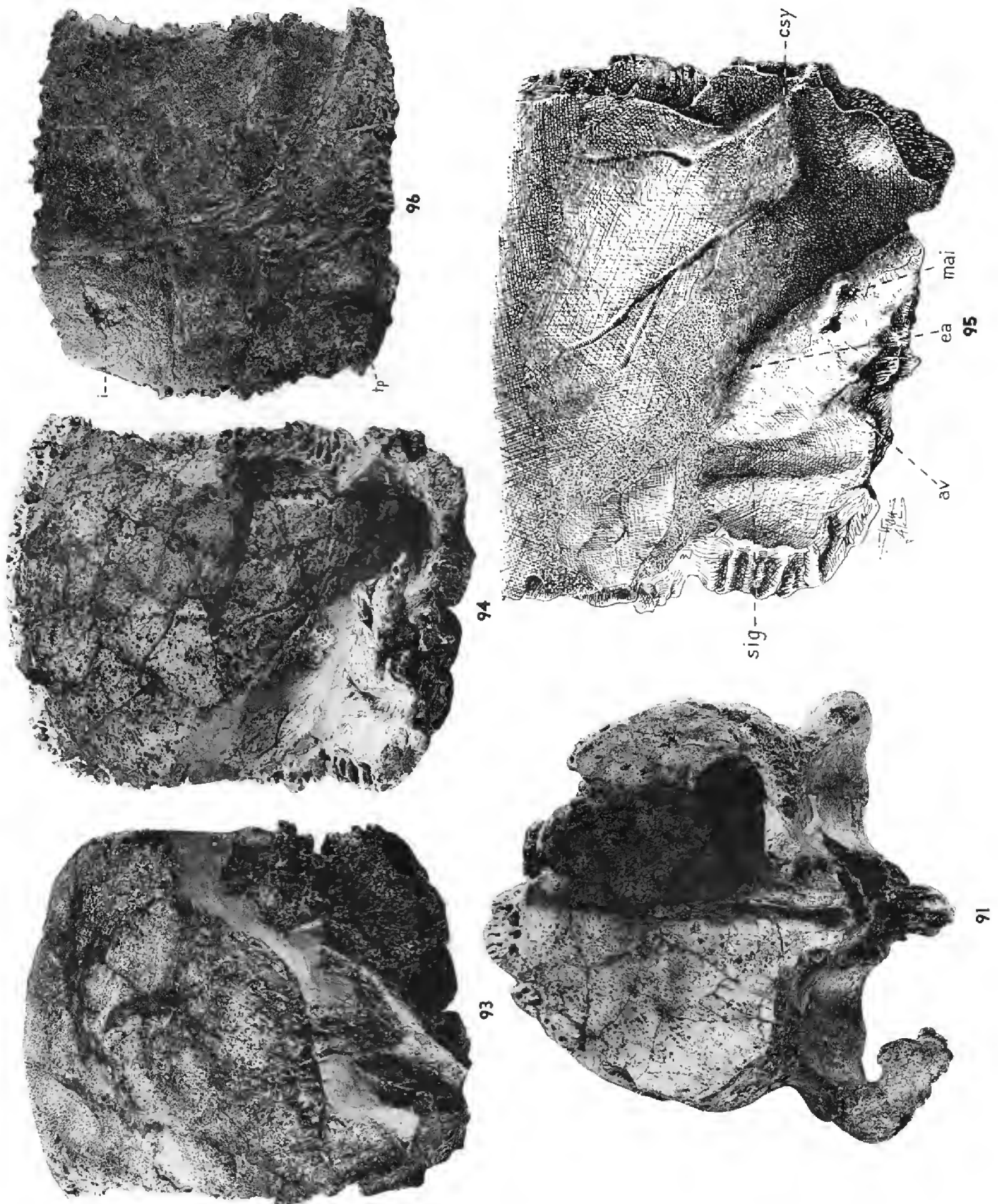
Fig. 97. Separate right parietal bone of *Sinanthropus* Skull XII. Cerebral side. Photograph from the original. 2/3. Abbreviations: csy, crista sylvii; tp, torus angularis.

Fig. 98. Contours of the coronal margin (A) and the lambdoid margin (B) of the left parietal bone of *Sinanthropus* Skull XII (heavy line), compared with the corresponding margins of a modern human skull (dotted line). 2/3. Abbreviations: am, angulus mastoideus; csy, crista sylvii; ssg, sutura sagittalis.

Fig. 99. Separate occipital bone of *Sinanthropus* Skull XII. Viewed from behind and below. Photograph from the original. 2/3.

Fig. 100. Separate occipital bone of *Sinanthropus* Skull XII. Cerebral side. Photograph from the original. 2/3. Abbreviations: ec, eminentia cruciata; fc, fossa cerebralis; fcl, fossa cerebellaris; fmg, foramen occipitale; oa, os epactale; str, sulcus transversus; sus, sulcus sagittalis.

Fig. 101. Separate left temporal bone of *Sinanthropus* Skull III—Skull of Locus E (Black). Lateral view. Drawing from the original. 1/1. Abbreviations: cm, crista mastoidea; cs, crista supramastoidea; fma, foramen mastoideum; im, incisura mastoidea; ip, incisura parietalis; fm, foramen mastoideum; scp, spina cristae petrosae.

Fig. 102. Separate right temporal bone of *Sinanthropus* Skull III—Skull of Locus E (Black). Lateral view. Drawing from the original. 1/1. Abbreviations: cm, crista mastoidea; cpg, crista postglenoidalis; cs, crista supramastoidea; i, injury; im, incisura mastoidea; ip, incisura parietalis; pm, processus mastoideus; scp, spina cristae petrosae.

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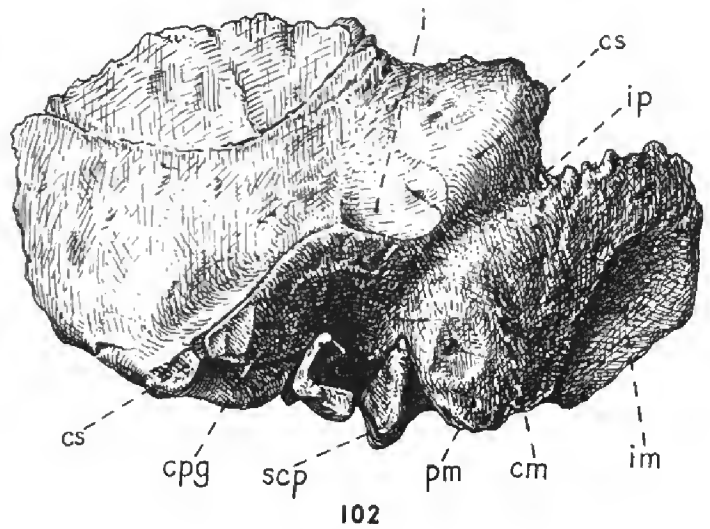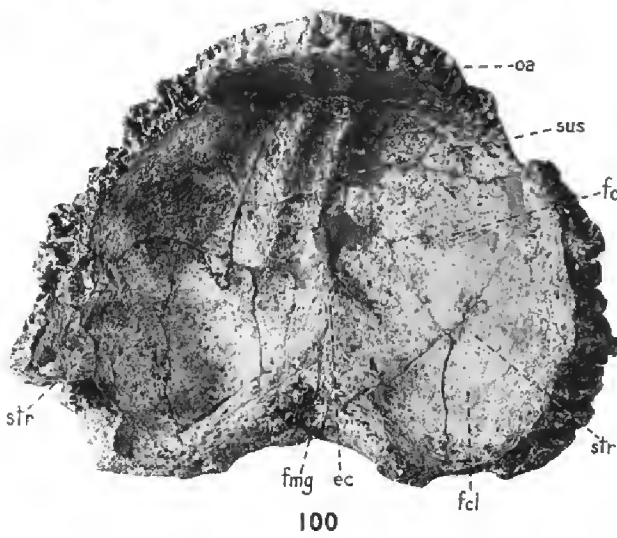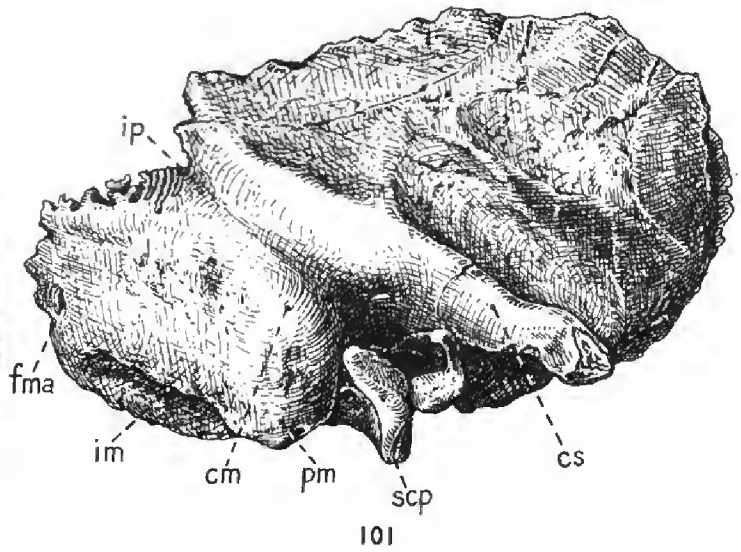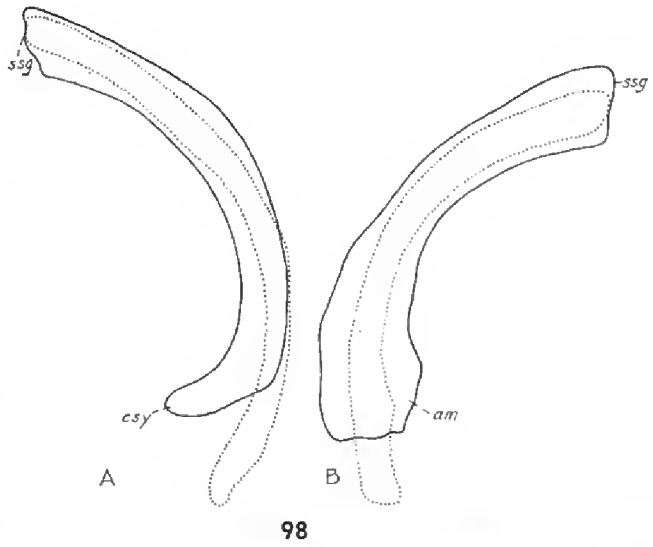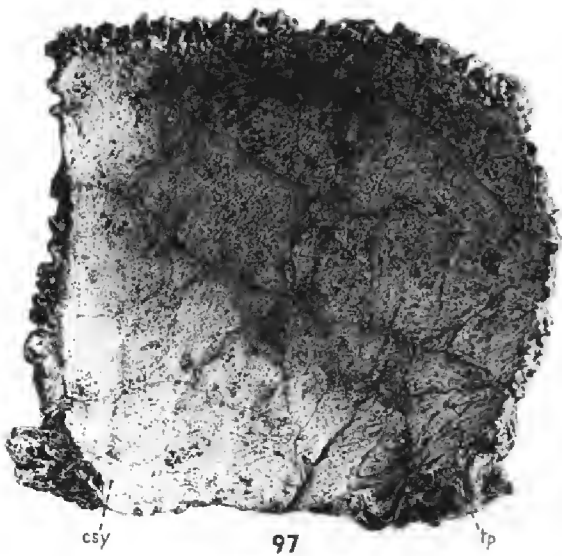
Fɪɢ. 103. Separate right temporal bone of *Sinanthropus* Skull III—Skull of Locus E (Black). Basal view (see also Figure 102). Drawing from the original. 1/1. Abbreviations: acc, apertura ext. canalic. cochl.; cc, canalis caroticus; com, crista occipitomastoidea; cpg, crista postglenoidalis; fg, fissura glaseri; fj, fossa jugularis; fm, fossa mandibularis; fp, foramen processus styloidei; fsm, foramen stylomastoideum; im, incisura mastoidea; lat, labium anterius tympanici; lpt, labium posterius tympanici; pae, porus acusticus ext.; pm, processus mastoideus; scp, spina cristae petrosae; ta, tuberculum articulare; tg, tegmen pori acustici.

Fɪɢ. 104. Left temporal bone of *Sinanthropus* Skull III—Skull of Locus E (Black). Basal view (see also Figure 101). Drawing from the original. 1/1. Abbreviations the same as in Figure 103. In addition: fs, foramen spinosum; rm, recessus medialis fossae mandibularis; som, sutura occipitomastoidea; sss, sutura sphenosquamosa.

Fɪɢ. 105. Right squama of the temporal bone of fragment *Sinanthropus* Skull VI (see Figures 33 and 36) —A— and the left squama of the temporal bone of *Sinanthropus* Skull V (see Figures 21–27) —B—. Both viewed from in front (cf. Fig. 246). Drawing from the original. 1/1. Abbreviations: csy, crista sylvii; pz, processus zygomaticus (base); ss, sutura squamosa.

Fɪɢ. 106. Ear region of *Sinanthropus* Skull X (cf. Figure 50). Lateral view. Photograph from the original. 1/1.

Fɪɢ. 107. Ear region of *Sinanthropus* Skull X (cf. Figures 50 and 56). Lateral view. Drawing from the original. 1/1. Abbreviations: cs, crista supramastoidea; ex, exostosis; im, incisura mastoidea; pm, processus mastoideus; scp, spina cristae petrosae.

Fɪɢ. 108. Right temporal bone of *Sinanthropus* Skull X (cf. Figures 54 and 60). Basal view. Drawing from the original. 1/1. Abbreviations: cpg, crista postglenoidalis; pae, porus acusticus ext.; pm, processus mastoideus; tg, tegmen pori acustici ext.
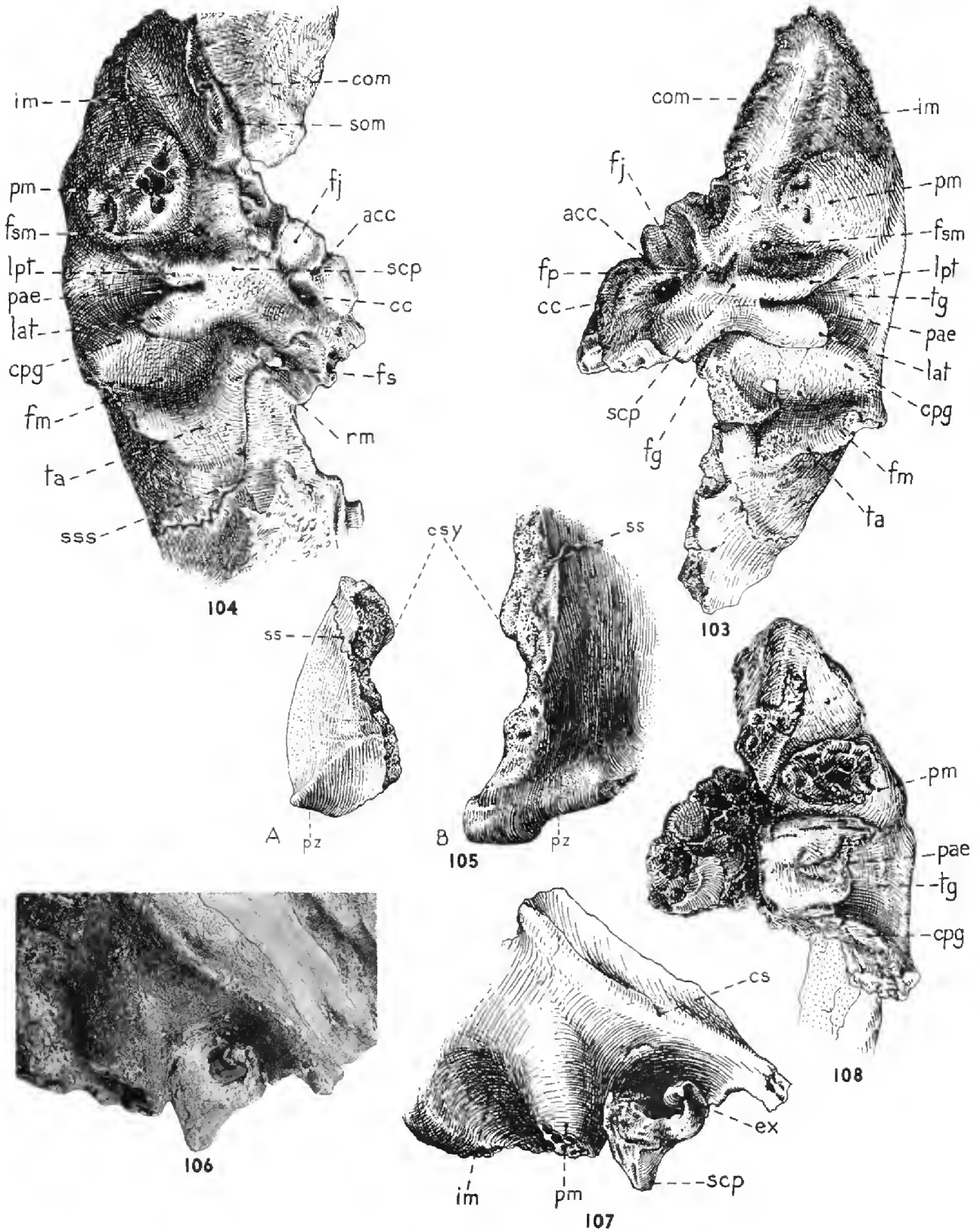
FIG. 109. Left temporal bone of *Sinanthropus* Skull XI (cf. Figures 61 and 67). Lateral view. Drawing from the original. 1/1. Abbreviations: bpp, basis process. pteryg.; cm, crista mastoidea; cs, crista supramastoidea; fm, fossa mandibularis; fma, foramen mastoideum; im, incisura mastoidea; ip, incisura parietalis; pm, processus mastoideus; scp, spina cristae petrosae; som, sutura occipitomastoidea.

FIG. 110. Left temporal bone of *Sinanthropus* Skull XI (cf. Figures 62 and 72). Basal view. Drawing from the original. 1/1. Abbreviations: bpp, basis processus pteryg.; com, crista occipitomastoidea; cpg, crista postglenoidalis; fov, foramen ovale (anterior border); fp, foramen processus styloidei (anterior border); im, incisura mastoidea; pm, processus mastoideus; rm, recessus medialis foss. mand.; scp, spina cristae petrosae; sss, sutura sphenosquamosa; ta, tuberculum articulare; tg, tegmen pori acust. ext.

FIG. 111. Left temporal bone of *Sinanthropus* Skull XII (cf. Figures 73 and 79). Lateral view. Drawing from the original. 1/1. Abbreviations: cm, crista mastoidea; cpg, crista postglenoidalis; cs, crista supramastoidea; fm, fossa mandibularis; im, incisura mastoidea; pm, processus mastoideus.

FIG. 112. Left temporal bone of *Sinanthropus* Skull XII (cf. Figures 78 and 84). Basal view. Drawing from the original. 1/1. Abbreviations: com, crista occipitomastoidea; fg, fissura glaseri; fj, fossa jugularis; fm, fossa mandibularis; fp, foramen processus styloidei; fsm, foramen stylomastoideum; im, incisura mastoidea; pm, processus mastoideus; som, sutura occipitomastoidea; sss, sutura sphenosquamosa; ta, tuberculum articulare; tg, tegmen pori acustici ext.

FIG. 113. Contour of the base of the temporal bone from the sphenoid region to the occipital drawn approximately through the middle of the mandibular fossa in obliquely sagittal direction from in front and medially to back and laterally. 1/2. A, *Sinanthropus* Skull XI, left side; B, *Sinanthropus* Skull III, left side; C, *Sinanthropus* Skull V, left side; D, Eskimo (A.M.N.H., no. 344); E, European (A.M.N.H. no. 1435 A); F, *Pithecanthropus* Skull II; G, *Pithecanthropus* Skull IV; H, gorilla, ♂ (A.M.N.H., no. 1460, A); I, orang-utang, ♂ (A.M.N.H., no. CA 2511); K, chimpanzee, ♂ (A.M.N.H., no. 382); L, *Paranthropus robustus*. Abbreviations: cpr, crista petrosa; fg, fissura glaseri; fm, fossa mandibularis; ftm, fissura temporomastoidea; pm, processus mastoideus; sss, sutura sphenosquamosa. The arrow indicates the anterior limit of the articular facet.
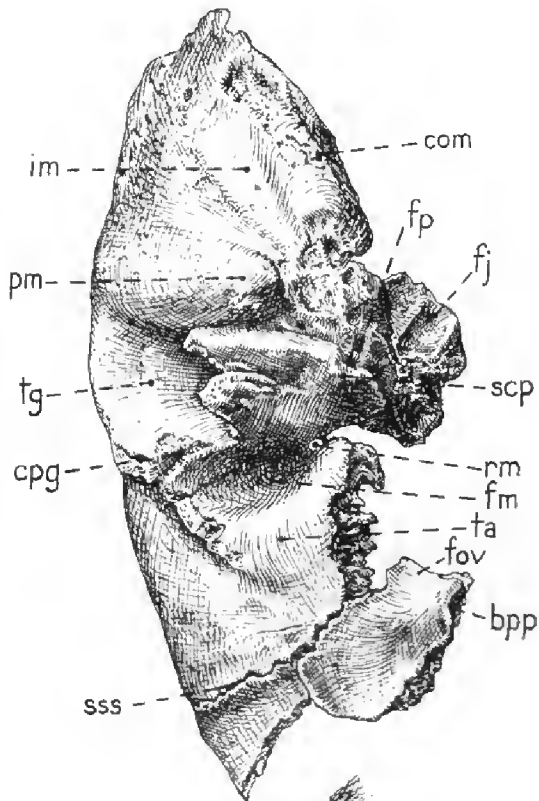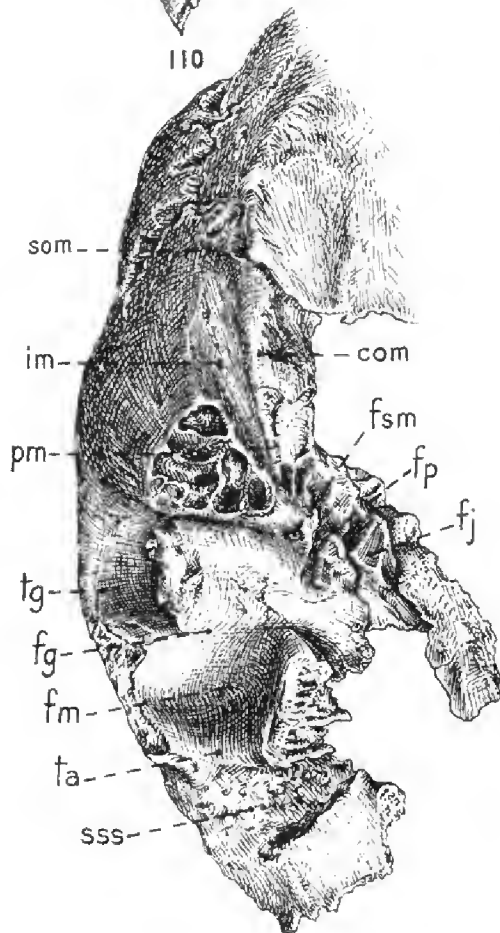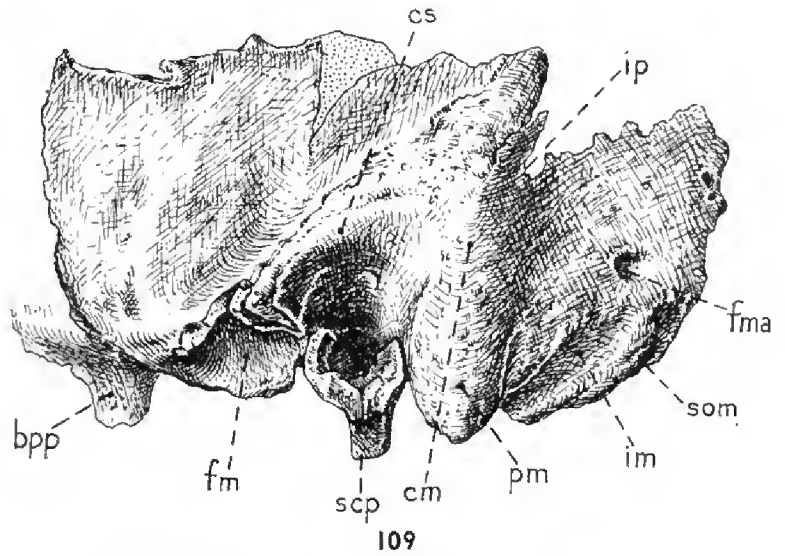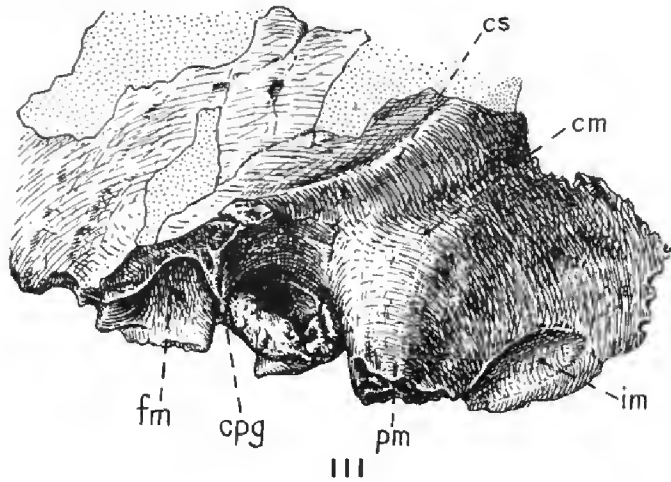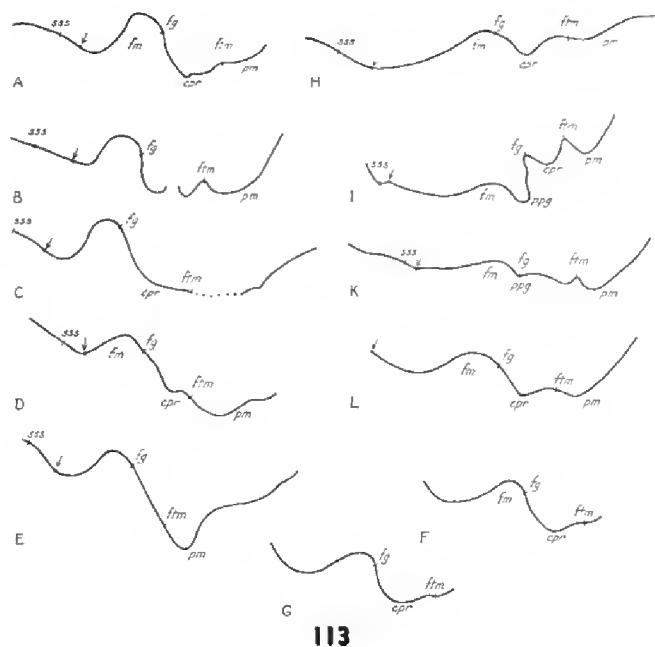
FIG. 114. Sagittal section through the mandibular joint of modern Man after Lubosch (1906, b). 2/3. A and B, types with deep mandibular fossae; C and D, types with shallow mandibular fossae. Abbreviations: c, condyle; fm, fossa mandibularis; m, meniscus; ta, tuberculum articulare.

FIG. 115. Sagittal section through the meniscus of the mandibular joint of adult orang-utang after Bluntschli (1929). Abbreviations: a, anterior; p, posterior.

FIG. 116. Diagram showing the topographic relation of the mandibular fossa to the pyramid and the middle cerebral fossa in vertical projection: cranial base horizontally orientated. Heavy lines outside contours; dotted lines inside contours. Mandibular fossa vertically shaded, cranial wall horizontally shaded. Modern Man. 1/2. Abbreviations: ba, basion; cpr, crista petrosa; fg, fissura glaseri; fj, fossa jugularis; fm, fossa mandibularis; fs, foramen spinosum; o, opisthion; po, porion; pst, processus styloid.; sss, sutura sphenosquamosa; ta, tuberculum articulare.

FIG. 117. The same diagram as in Figure 116. *Sinanthropus* Skull III. Restored contours in heavy dotted lines. 1/2. Abbreviations as in Figure 116.

FIG. 118. The same diagram as in Figures 116 and 117. Male gorilla (A.M.N.H., no. CA 1460). 1/2. Abbreviations as in Figure 116. ppg, processus postglenoidalis.

FIG. 119. The same diagram as in Figures 116, 117 and 118. *Pithecanthropus* Skull II. 1/2. Abbreviations as in Figure 116.

FIG. 120. The same diagram as in Figures 116–119. *Paranthropus robustus Broom.* 1/2. Abbreviations as in Figure 116.

FIG. 121. Left temporal bone in basal view. Modern Man, Australian aborigine, ♂ (S.M.F., no. 1222). 2/3. Abbreviations: cc, canalis caroticus; cp, crista petrosa; cpg, crista postglenoidalis; fm, fossa mandibularis; fsm, foramen stylomastoideum; im, incisura mastoidea; pam, processus entoglenoidalis; pj, processus jugularis; pst, processus styloideus; ptu, processus supratubalis; scp, spina cristae petrosae; ty, tympanicum.

FIG. 122. Right temporal bone in basal view. Female chimpanzee (S.M.F., no. 2495). 2/3. Abbreviations as in Figure 121: pal, processus ectoglenoidalis; ppg, processus postglenoidalis.

FIG. 123. Right temporal bone in basal view. Male gorilla (S.M.F., no. 1135). 2/3. Abbreviations the same as in Figures 121 and 122.
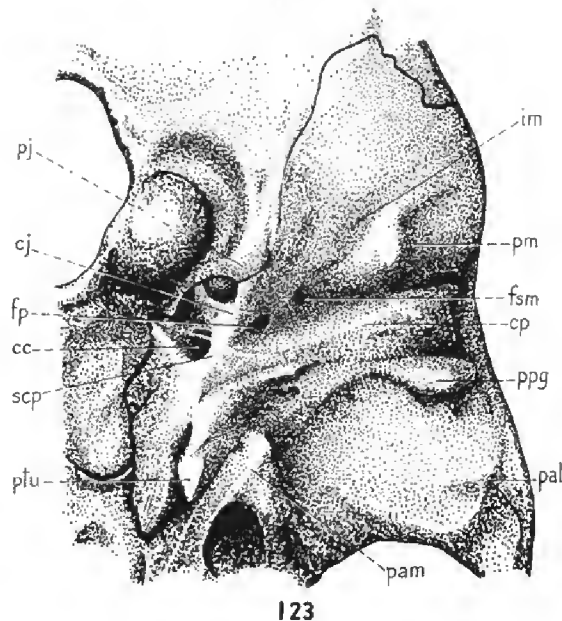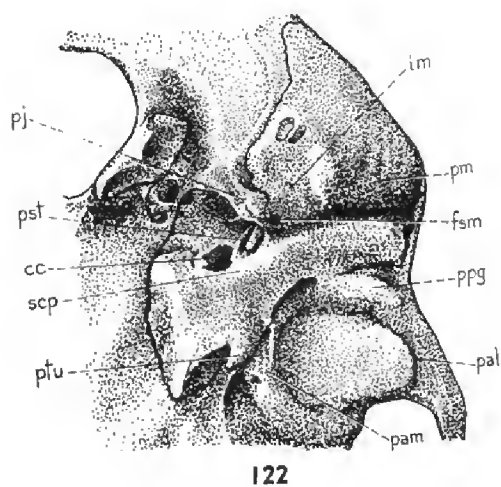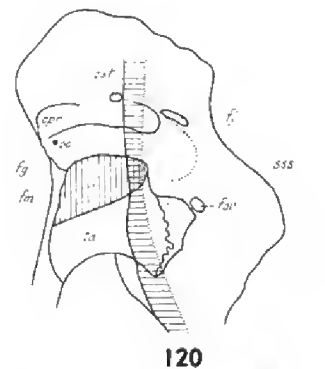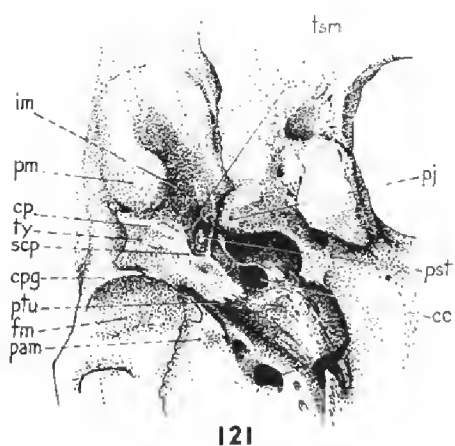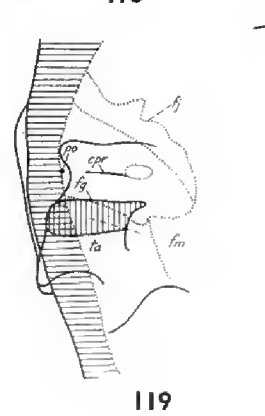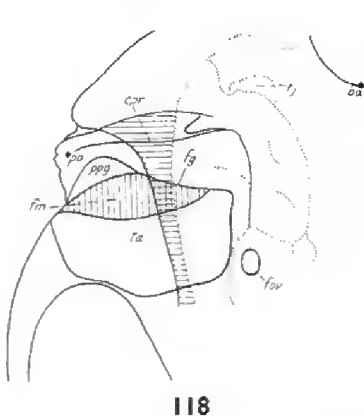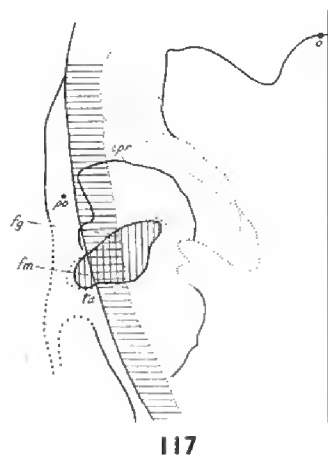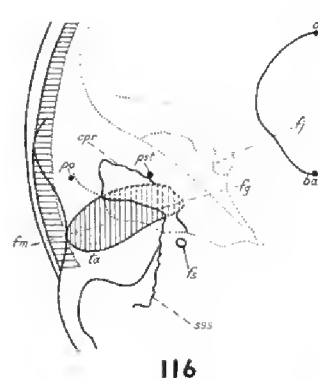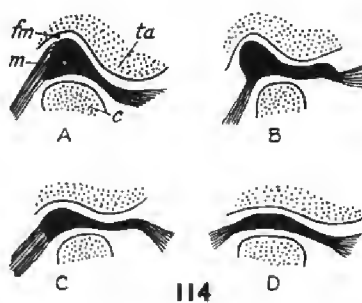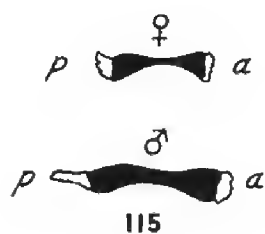
Fig. 124. Left tympanicum in basal view. Adult modern Man. After K. Buerkner (1878), Pl. VI–VII, Fig. 5. 2/3. Fissure and perforation of the tympanic plate.

Fig. 125. Diagram showing the topographic relation of the tympanic plate and the basal aspect of the pyramid to the cerebral contours of the pyramid. Outside contours in heavy lines, inside contours in dotted lines. Male European (A.M.N.H., no. 1435 A). 1/2. Abbreviations: ba, basion; cc, canalis caroticus; co, condylus; msp, margo superior pyramidis; p, basal surface of the pyramid; ty, tymanicum.

Fig. 126. The same diagram as in Figure 125. *Sinanthropus* Skull III. 1/2. Abbreviations as in Figure 125.

Fig. 127. The same diagram as in Figure 125. Male gorilla (A.M.N.H., no. CA 1460). 1/2. Abbreviations the same as in Figure 125: fo, foramen ovale; fp, foramen processus styloidei; fsm, foramen stylomastoideum.

Fig. 128. The same diagram as in Figure 125. Male orang-utang (A.M.N.H., no. CA 2511). 1/2. Abbreviations as in Figure 125.

Fig. 129. Orientation of the longitudinal axis of the pyramid (viewed from the base of the cranium) to the midline. *Sinanthropus* Skull III, heavy lines; male gorilla (A.M.N.H., no. CA 1460), dashed lines; modern Man (European; A.M.N.H., no. 1435 A) dotted lines. 1/2. o, opisthion.

Fig. 130. Fossa cerebralis media (right moiety) of an Australian aborigine. 2/3. Abbreviations: csy, crista sylvii; fca, facies cerebralis anterior; fcm, facies cerebralis media; fcp, facies cerebralis posterior; msp, margo superior pyramidis.

Fig. 131. Fossa cerebralis media (right moiety) of a female gorilla. 2/3. Abbreviations: map, margo alae parvae. Remaining abbreviations as in Figure 130.

Fig. 132. Fossa cerebralis media (right moiety) of a male chimpanzee. 2/3. Abbreviations as in Figures 130 and 131.

Fig. 133. Outer contours of the facies temporalis (ft) and facies infratemporalis (fit) of the left sphenoid, orientated approximately in a frontal plane. The point indicates the position of the crista infratemporalis. 2/3. A, orang-utang, ♂; B, gorilla, ♂; C, *Sinanthropus* Skull II; D, chimpanzee, ♂; E, modern Man ♂ (European).
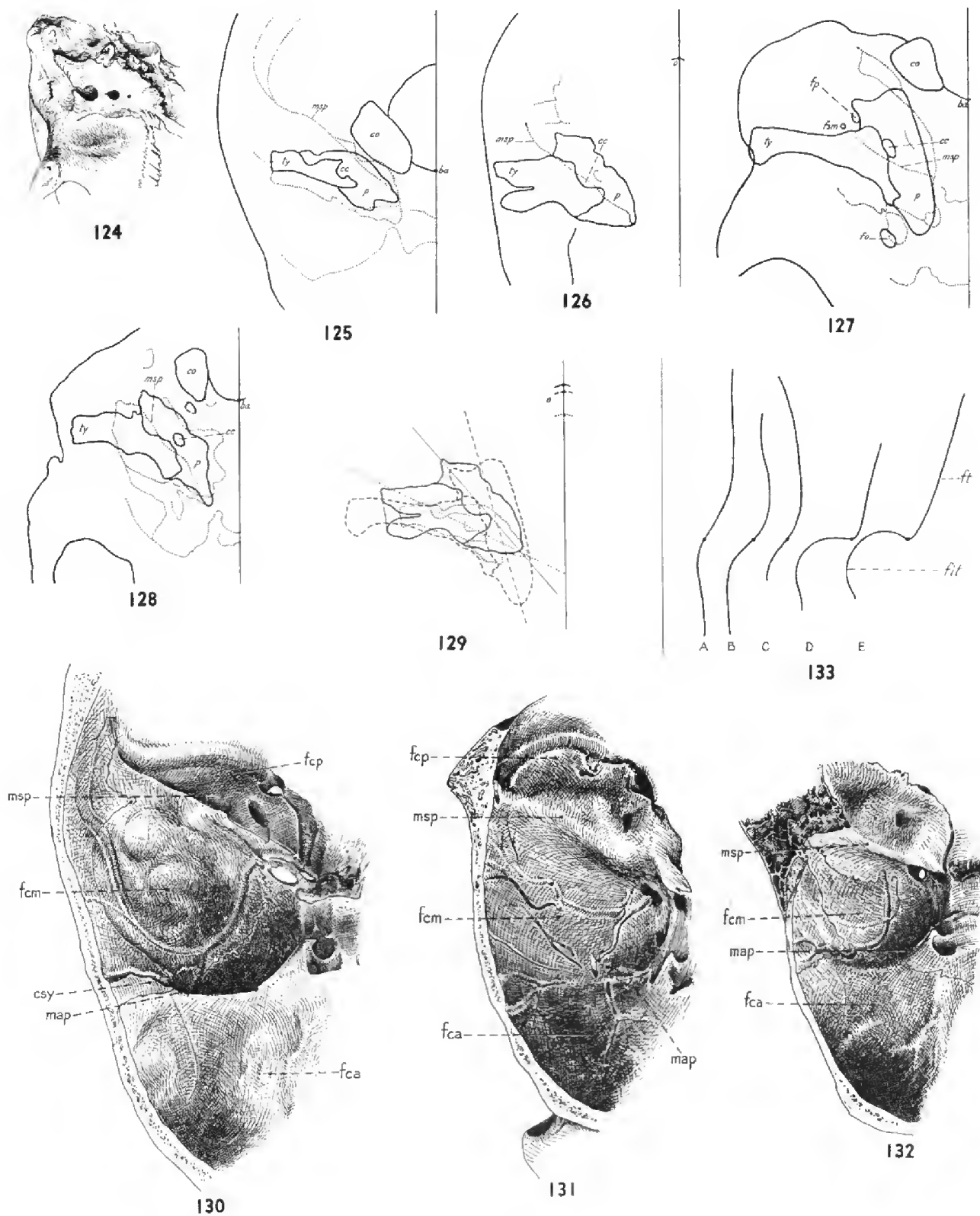
Fig. 134. Contours of a cross-section in horizontal plane through the left greater wing of the sphenoid of a European (. . .), *Sinanthropus* Skull II (———); and female orang-utang (– – – – –). 1/1. Abbreviations: fc, facies cerebralis; fo, facies orbitalis; ft, facies temporalis.

Fig. 135. Processus frontalis of a left maxilla of *Sinanthropus* (probably of Skull X; see No. I of the Catalogue of Facial Bones in Table I). Photograph from the original. 1/1. A, facial view; B, medial view.

Fig. 136. Processus frontalis of a left maxilla of *Sinanthropus* (probably Skull X; see Figure 135). Drawing from the original. 1/1. A, facial view; B, medial view; C, lateral view. Abbreviations: cco, crista conchalis; cem, crista ethmoidalis; cla, crista lacrimalis anterior; in, incisura nasalis; mio, margo infraorbitalis; ml, margo lacrimalis; slm, sulcus lacrimalis; sma, sinus maxillaris.

Fig. 137. Contours of the left nasal bone of *Sinanthropus* Skull XII. The reconstructed part indicated by dashed lines. 1/1. A, frontal view; B, lateral view.

Fig. 138. Horizontal contour of the nasal saddle in norma verticalis. The points indicate from left to right: crista lacrimalis, sutura nasomaxillaris; sutura internasalis. 1/1. A, Modern Man (Siamese, ♀); B, Modern Man (Hungarian, ♂).

Fig. 139. Horizontal contour of the nasal saddle as in Figure 138. 1/1. A, *Sinanthropus* Skull XII; B, Rhodesian Skull; C, Gibraltar Skull.

Fig. 140. Horizontal contour of the nasal saddle as in Figure 138. 1/1. A, gorilla, ♂; B, chimpanzee, ♂; C, orang-utang, ♀.

Fig. 141. Contour in profile of glabellar torus, infraglabellar notch and nasal bridge of *Sinanthropus* Skull XII (A), Gibraltar Skull (B), Krapina Skull No. C (C), Rhodesian Skull (D), Skull of La Chapelle-aux-Saints (E), Siamese (F), Hungarian (G). 2/3. The point indicates the nasion.

Fig. 142. Left maxilla of *Sinanthropus* (see No. V of the Catalogue of Facial Bones in Table I). M₃ fixed with plastiline. Lateral view. Photograph from the original. 1/1.

Fig. 143. Left maxilla of *Sinanthropus* (see No. V of the Catalogue of Facial Bones in Table I). Frontal view. Drawing from the original. I¹ and C reconstructed. 1/1. Abbreviations: ex, exostoses; fcn, fossa canina; ima, incisura malaris; jac, jugum alveolare canini; pz, processus zygomaticus maxillae.

Fig. 144. Left maxilla of *Sinanthropus* (No. V); see Figures 142 and 143. Lateral view. Clivus nasoalveolaris and tuber maxillare reconstructed. Drawing from the original. 1/1. Abbreviations as in Figure 143.
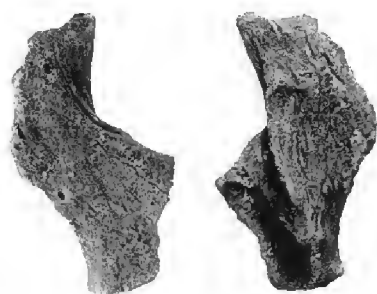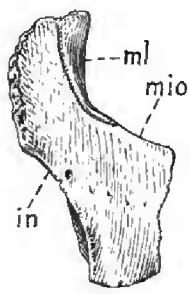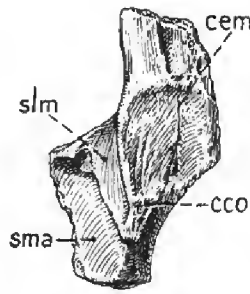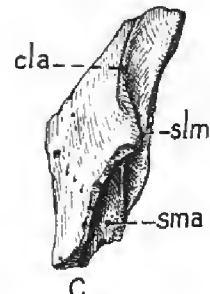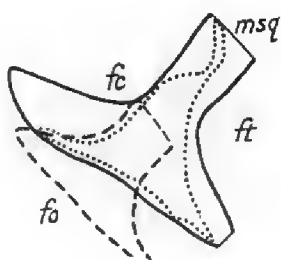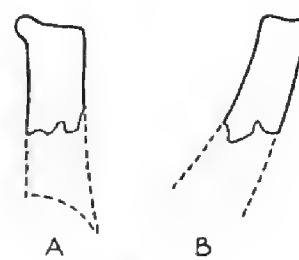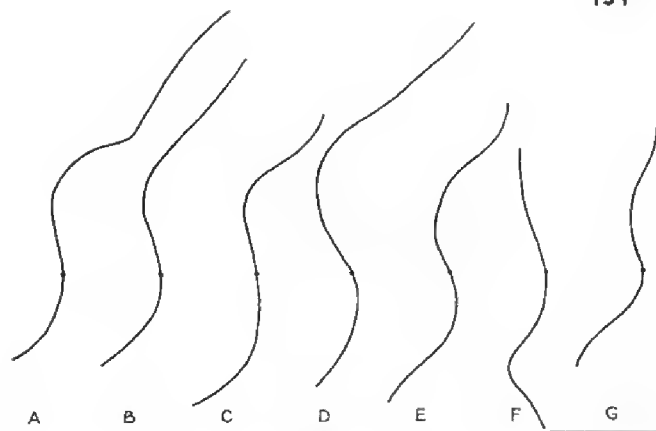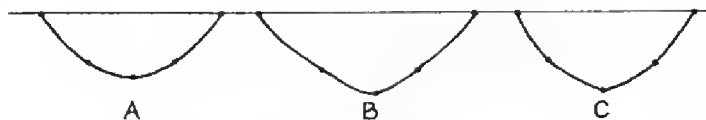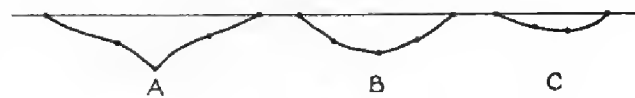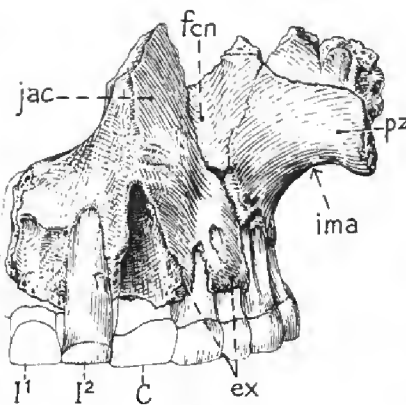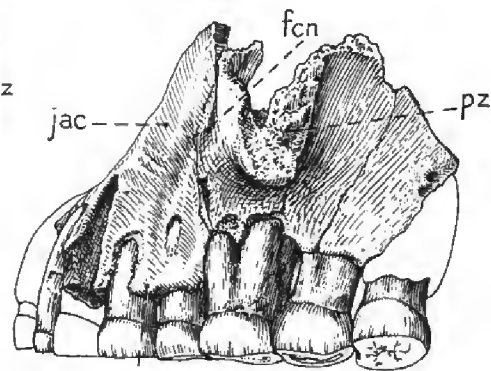
FIG. 145. Left maxilla of *Sinanthropus* (No. V); see Figures 142–144. Medial view. Clivus nasoalveolaris and tuber maxillare reconstructed. Drawing from the original. 1/1. Abbreviations: cic, canalis incisivus; cme, crista palatina mediana; mn, meatus nasi; sma, sinus maxillaris.

FIG. 146. Left maxilla of *Sinanthropus* (No. V); see Figures 142–145. Viewed from above. Drawing from the original. 1/1. Abbreviations: mip, margo inferior apert. pirif.; mn, meatus nasi; pz, processus zygomaticus maxillae; sma, sinus maxillaris.

FIG. 147. Left maxilla of *Sinanthropus* (No. V); see Figures 142–146. Viewed from below. Drawing from the original. 1/1. Abbreviations as in Figures 145 and 146.

FIG. 148. Left maxilla of *Sinanthropus* (probably belonging to Skull XI; see No. III of the Catalogue of Facial Bones in Table I. Lateral view. Photograph from the original. 1/1.

FIG. 149. Left maxilla of *Sinanthropus* (No. III), see Figure 148. Frontal view. Drawing from the original. 1/1. Abbreviations: ex, exostosis; ima, incisura malaris; pz, processus zygomaticus maxillae; sma, sinus maxillaris.

FIG. 150. Left maxilla of *Sinanthropus* (No. III), see Figure 148. Lateral view. Drawing from the original. 1/1. Abbreviations as in Figure 149.

FIG. 151. Left maxilla of *Sinanthropus* (No. III), see Figures 149 and 150. Medial view. Drawing from the original. 1/1. Abbreviation: sma, sinus maxillaris.

FIG. 152. Left maxilla of *Sinanthropus* (No. III), see Figures 149–151. Viewed from below. Drawing from the original. 1/1. Abbreviations as in Figure 149.

FIG. 153. Left maxilla of the "Upper Cave," probably belonging to *Sinanthropus* (see No. VI of the Catalogue of Facial Bones in Table I). Lateral view. Photograph from the original. 1/1. Abbreviation: ex, exostosis.

FIG. 154. Left maxilla of the "Upper Cave" (No. VI); see Figure 153. Medial view. Photograph from the original. 1/1.

FIG. 155. Left maxilla of the "Upper Cave" (No. VI); see Figures 153 and 154). Medial view. Drawing from the original. 1/1. Abbreviations: cco, crista conchalis; mn, meatus nasi.

FIG. 156. Left maxilla of the "Upper Cave" (No. VI); see Figures 153–155. Viewed from below. Drawing from the original. 1/1. Abbreviation: ex, exostosis.

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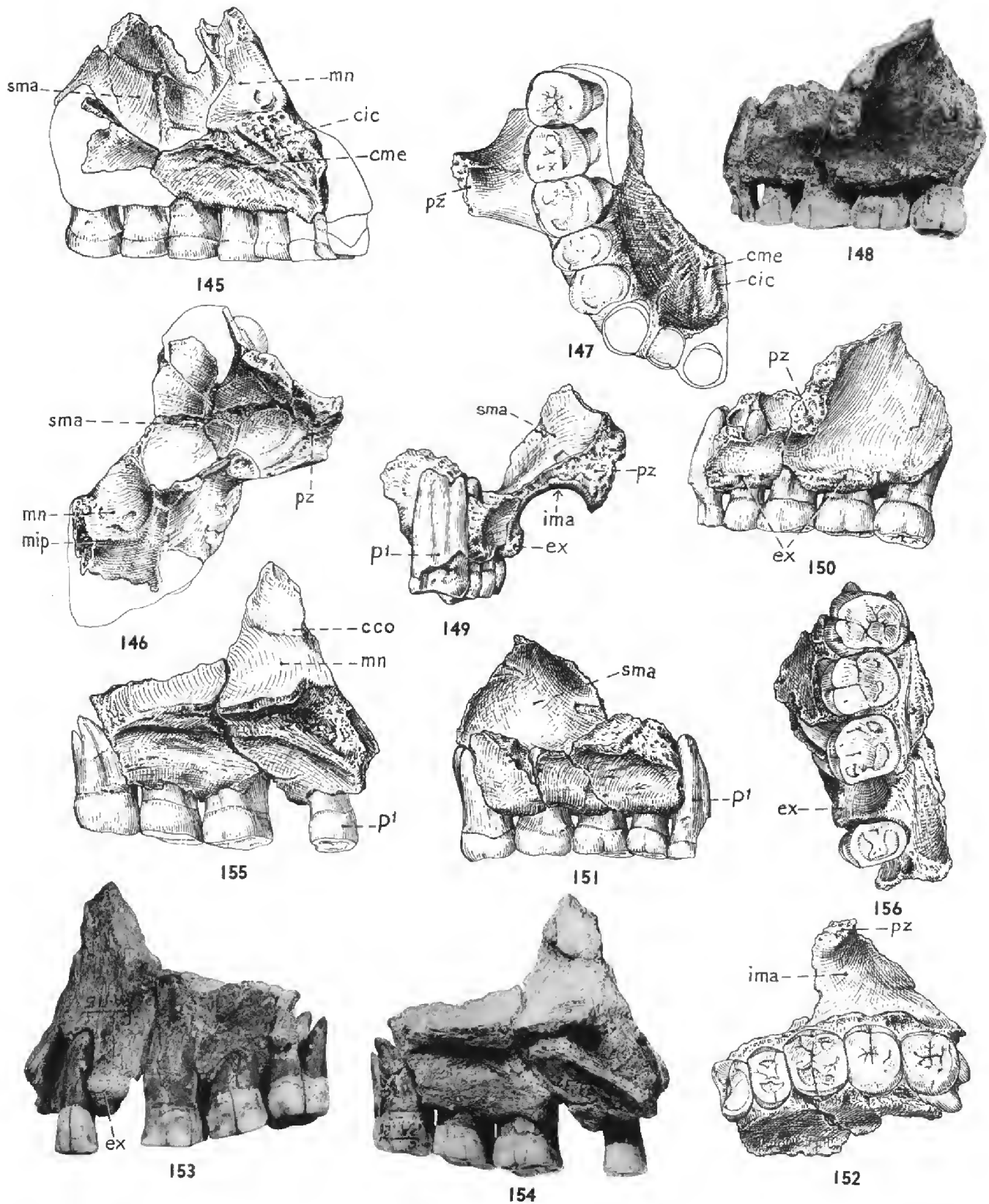
Fɪɢ. 157.   Fragment of a palate of *Sinanthropus*, right side; probably belonging to Skull XI (No. IV, see Catalogue of Facial Bones in Table I).   Viewed from below.   Photograph from the original.   1/1.

Fɪɢ. 158.   Fragment of a palate of *Sinanthropus* (No. IV), see Figure 157.   Viewed from below.   Drawing from the original.   1/1.   Abbreviation: spl, sulcus palatinus medialis.

Fɪɢ. 159.   Fragment of a palate of *Sinanthropus* (No. IV); see Figures 157 and 158; superimposed on the palate of a neolithic North Chinese of about the same size.   2/3.   Abbreviations as in Figure 158.

Fɪɢ. 160.   Fragment of a left os zygomaticum of *Sinanthropus*, probably belonging to Skull X (No. II of the Catalogue of Facial Bones in Table I).   Lateral view.   Photograph from the original.   1/1.

Fɪɢ. 161.   Fragment of a left os zygomaticum (No. II), see Figure 160.   Lateral view.   Drawing from the original.   1/1.   Abbreviations: fzf, foramen zygomaticofaciale; mio, margo infraorbitalis; tm, tuber malare.

Fɪɢ. 162.   Fragment of a left os zygomaticum (No. II), see Figures 160 and 161.   Viewed from behind.   Drawing from the original.   1/1.   Abbreviations: fo, facies orbitalis; ft, facies temporalis; fzo, foramen zygomaticoorbitale; sma, sinus maxillaris.

Fɪɢ. 163.   Fragment of a left os zygomaticum (No. II), see Figures 160–162.   Viewed from below.   Drawing from the original.   1/1.   Abbreviations: szm, sutura zygomaticomaxillaris; tm, tuber malare.

Fɪɢ. 164.   Horizontal outer contour of the left maxilla from the apertura piriformis to the sutura zygomatico-maxillaris (szm).   The midline is indicated by the straight line to the left.   2/3.   A, gorilla ♂; B, chimpanzee ♂; C, *Sinanthropus* maxilla No. V (Figures 142–147); D, Rhodesian Skull; E, New Britain ♂; F, European ♂; G, Amerindian ♂.   Abbreviations: fn, facies nasalis; fcn, fossa canina; jac, jugum alveolare canini; pz, processus zygomaticus maxillae.

Fɪɢ. 165.   Outer and inner contours of the zygomatic process of the maxilla and the zygomatic arch, viewed from the base of the skull.   2/3.   A, Mongolian ♀; B, *Sinanthropus*, (fragment No. II); C, gorilla ♂; D, Alaska Eskimo ♂; E, Greenland Eskimo ♂; F, Rhodesian Skull; G, European ♂; H, New Caledonian ♂; I, chimpanzee ♂; K, orang-utang ♂.   Abbreviations: ft, facies temporalis; szt and dotted line, sutura zygomaticotemporalis.
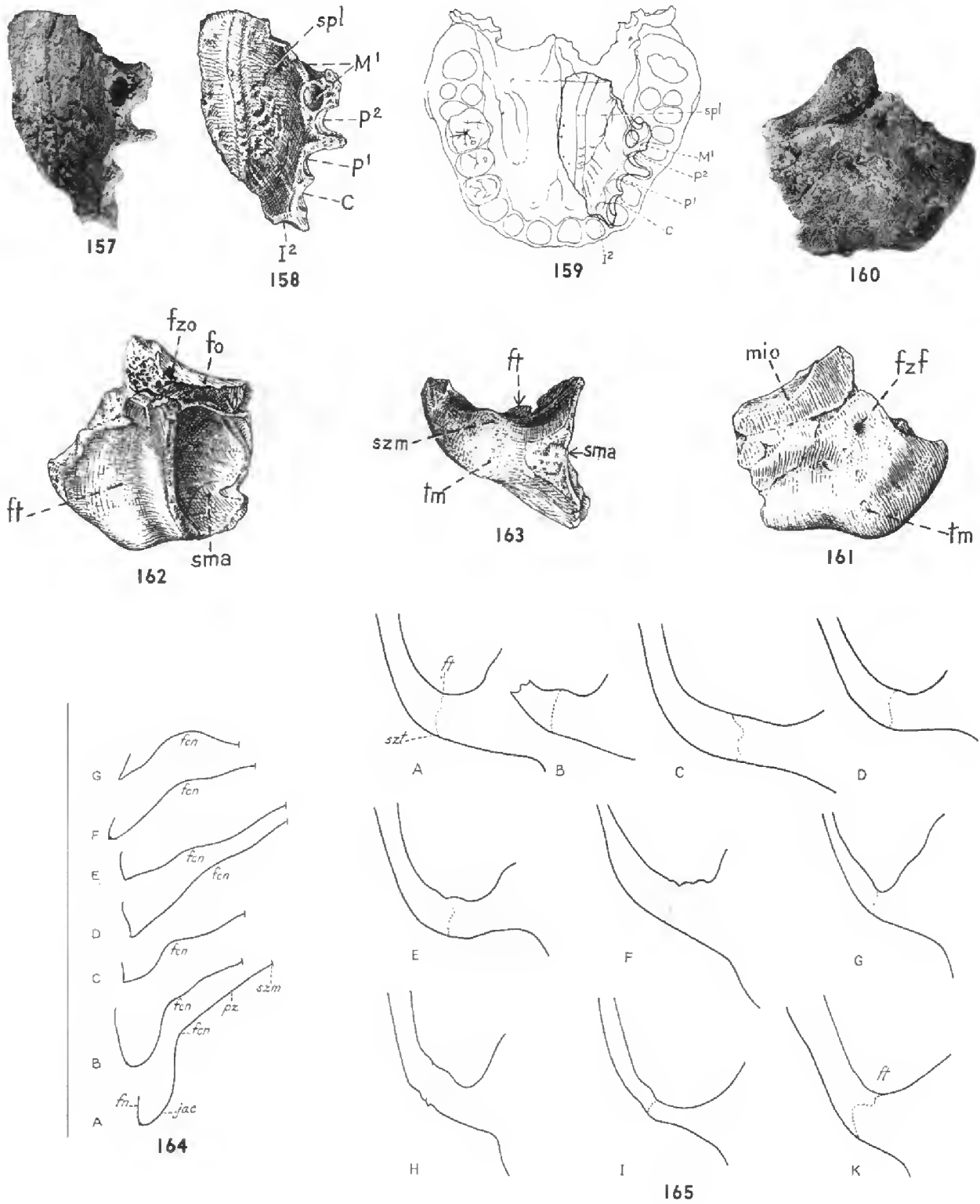
Fɪɢ. 166. Contours of the frontosphenoidal process of the zygomatic bone traced at the level of the greatest breadth in norma basilaris. The straight line runs 25 mm. to the right of the midline. The inclination-angle of the facies malaris is represented by the angle the dotted line forms with the straight line. 2/3. A, chimpanzee ♂; B, gorilla ♂; C, Alaska Eskimo ♂; D, Greenland Eskimo ♂; E, orang-utang ♂; F, *Sinanthropus* Skull XII ♂; G, New Caledonian ♂; H, European ♂; I, Rhodesian Skull. Abbreviations: fml, facies malaris; fo, facies orbitalis; ft, facies temporalis.

Fɪɢ. 167. Contours of the zygomatic and frontosphenoidal processus traced at the greatest breadth. 2/3. A, gorilla ♂; B, Rhodesian Skull; C, Mongolian ♂; D, *Sinanthropus* Skull XII; E, European ♂. Abbreviations: ft, facies temporalis; izf, incisura zygomaticofrontalis; izt, incisura zygomaticotemporalis; pgm, processus marginalis.

Fɪɢ. 168. Female gorilla (A); reconstructed *Sinanthropus* skull (B); male North Chinese (C). 1/3. The three skulls orientated in norma lateralis sinistra.

Fɪɢ. 169. Female gorilla (A); reconstructed *Sinanthropus* skull (B); male North Chinese (C). 1/3. The three skulls orientated in norma frontalis.
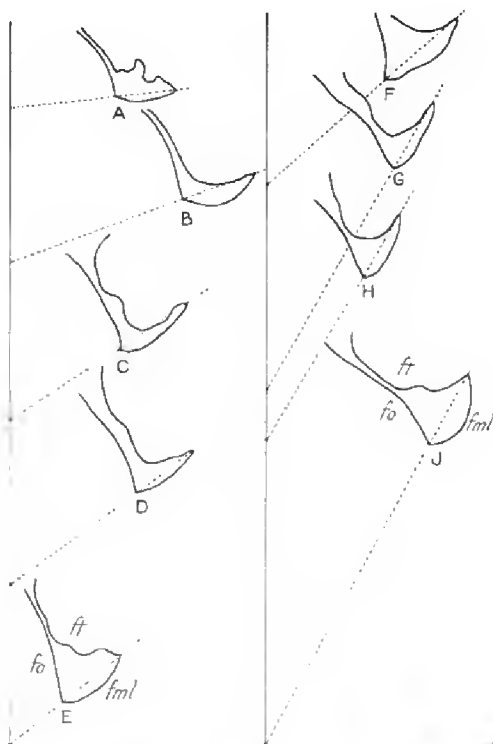
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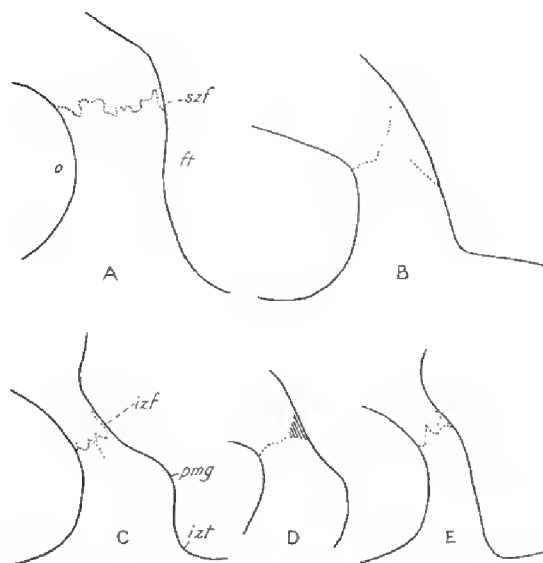
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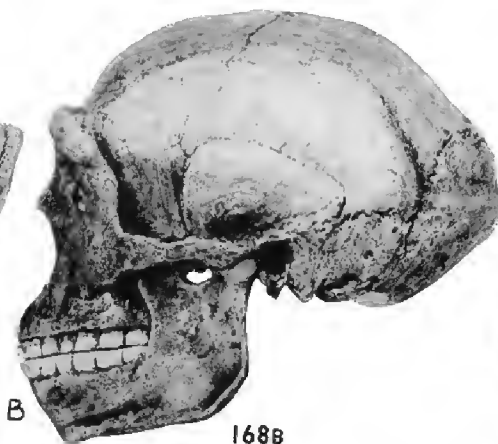
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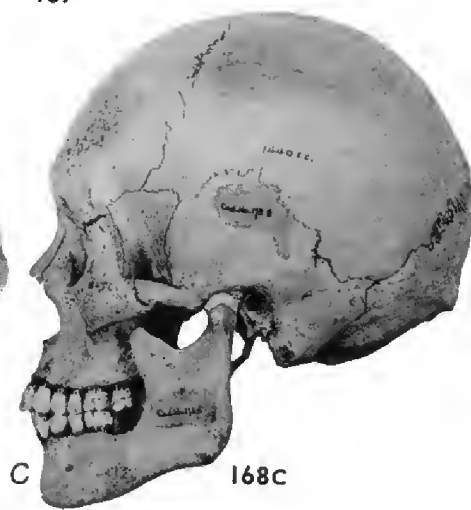
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FIG. 170.   Female gorilla (A); reconstructed *Sinanthropus* skull (B); male North Chinese (C).   1/3.   The three skulls orientated in norma occipitalis.

FIG. 171.   Female gorilla (A), reconstructed *Sinanthropus* skull (B); male North Chinese (C).   1/3.   The three skulls orientated in norma verticalis.

FIG. 172.   Female gorilla (A); reconstructed *Sinanthropus* skull (B); male North Chinese (C).   1/3.   The three skulls orientated in norma basalis.
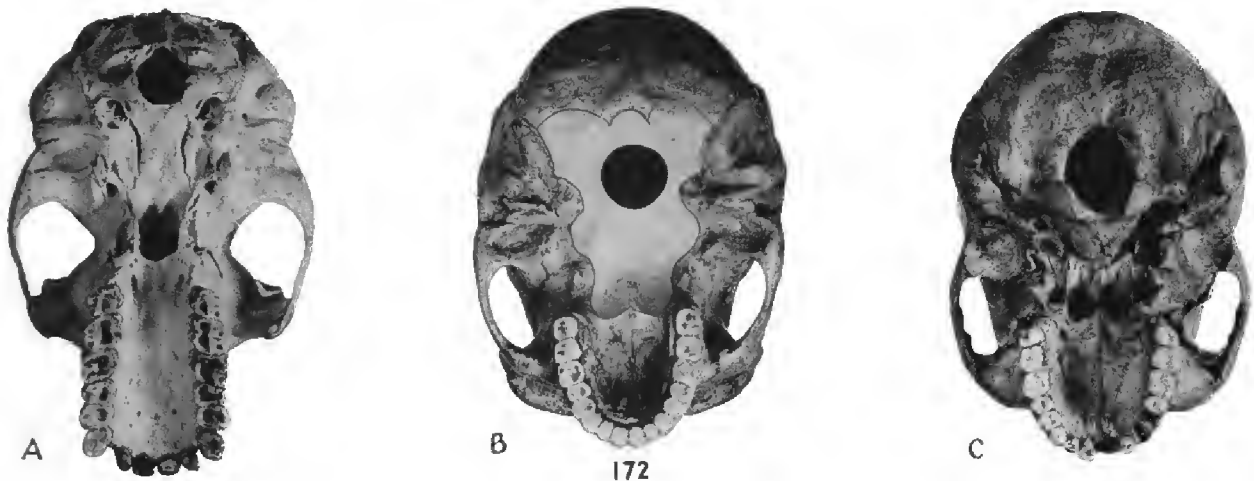
Fɪɢ. 174. Reconstruction of the head of a *Sinanthropus* woman (A); the skull on which the reconstruction was made (B). The reconstruction of the head was made with the kind assistance of Mrs. Lucille Swan. 1/3. Norma lateralis sinistra.

Fɪɢ. 175. Reconstruction of the head of a *Sinanthropus* woman (A); the skull on which the reconstruction was made (B). 1/3. Norma frontalis.

Fɪɢ. 176. Reconstruction of the head of a *Sinanthropus* woman (A); the skull on which the reconstruction was made (B). 1/3. Three quarters-profile.

Fɪɢ. 173. See Plate XLIX.

A   174A

174B   B

A   175A

B   175B

A   176A

176B   B
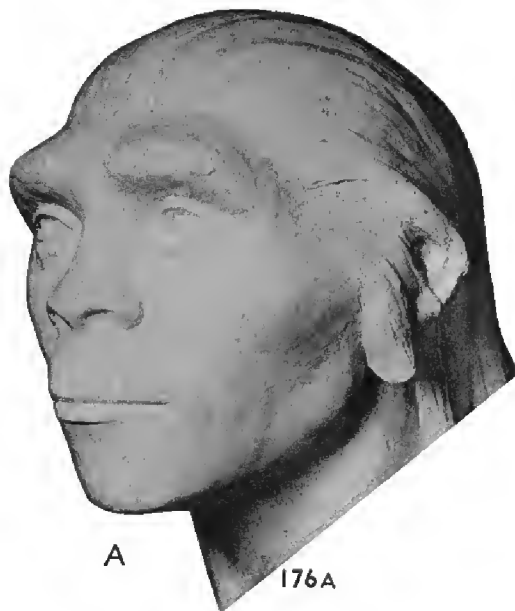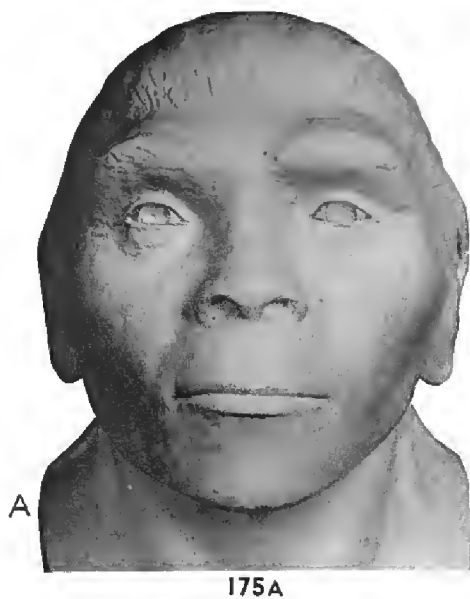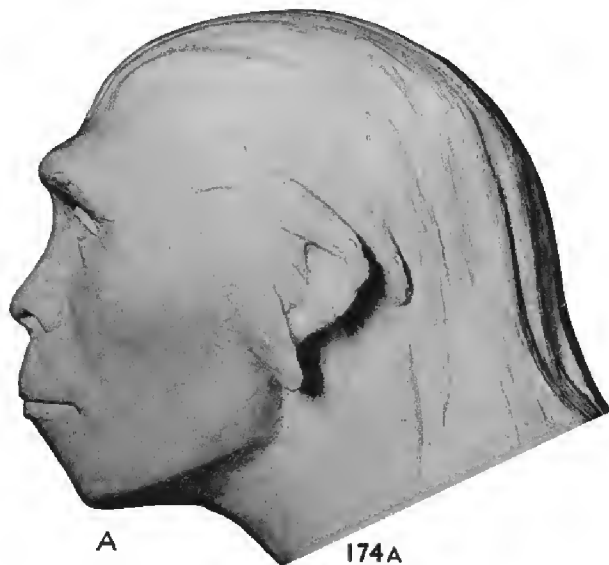
Fɪɢ. 173. Reconstructed *Sinanthropus* Skull in norma basalis. 1/2.

Fɪɢ. 177. Reconstructed head of a *Sinanthropus* woman with the left half of the skull exposed. 1/3. Norma lateralis sinistra.

Fɪɢ. 178. Reconstruction of the head of a *Sinanthropus* woman with the left half of the skull exposed. 1/3. Norma frontalis.

Fɪɢ. 179. Reconstruction of the head of a *Sinanthropus* woman with the left half of the skull exposed. 1/3. Three quarters-profile.

Fɪɢs. 174–176. See Plate XLVIII.
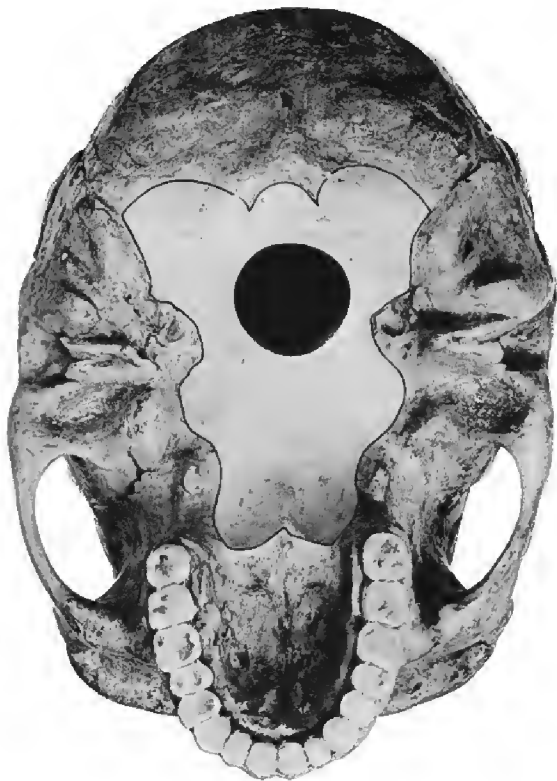
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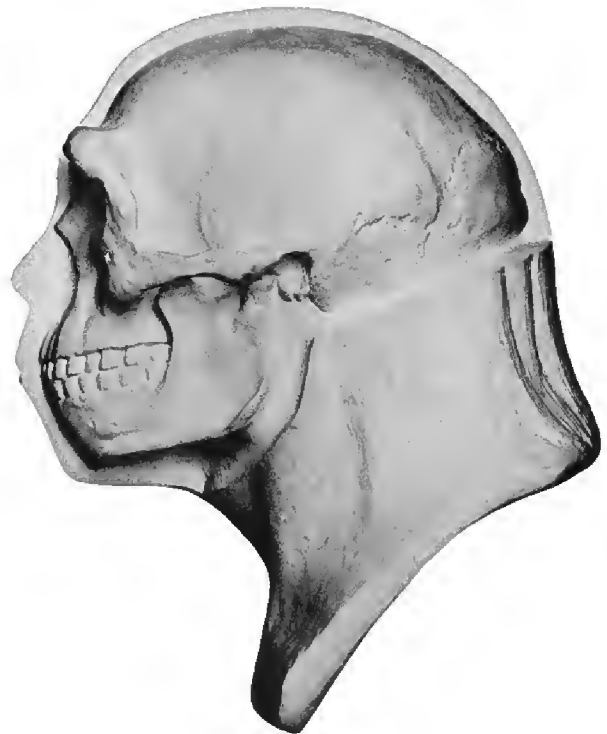
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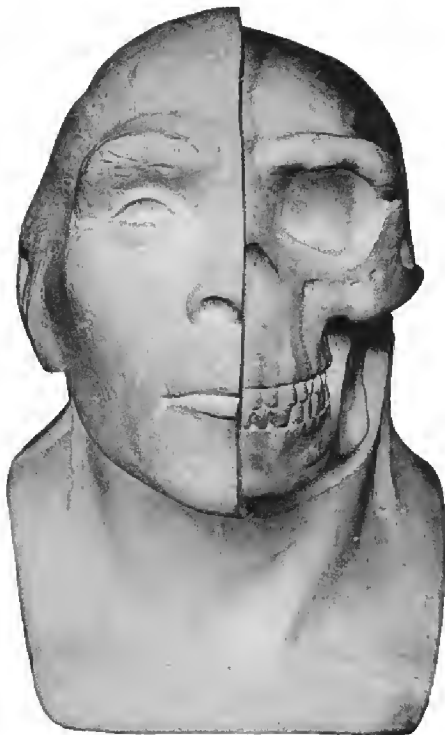
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Fig. 180. Mid-sagittal craniogram of the reconstructed *Sinanthropus* skull. 1/1. Abbreviations: b, bregma; ba, basion; gn, gnathion; i, inion; id, incision; l, lambda; n, nasion; ns, nasospinale; o, opisthion; op, opisthocranion; or, orbiculare; po, porion; v, vertex.

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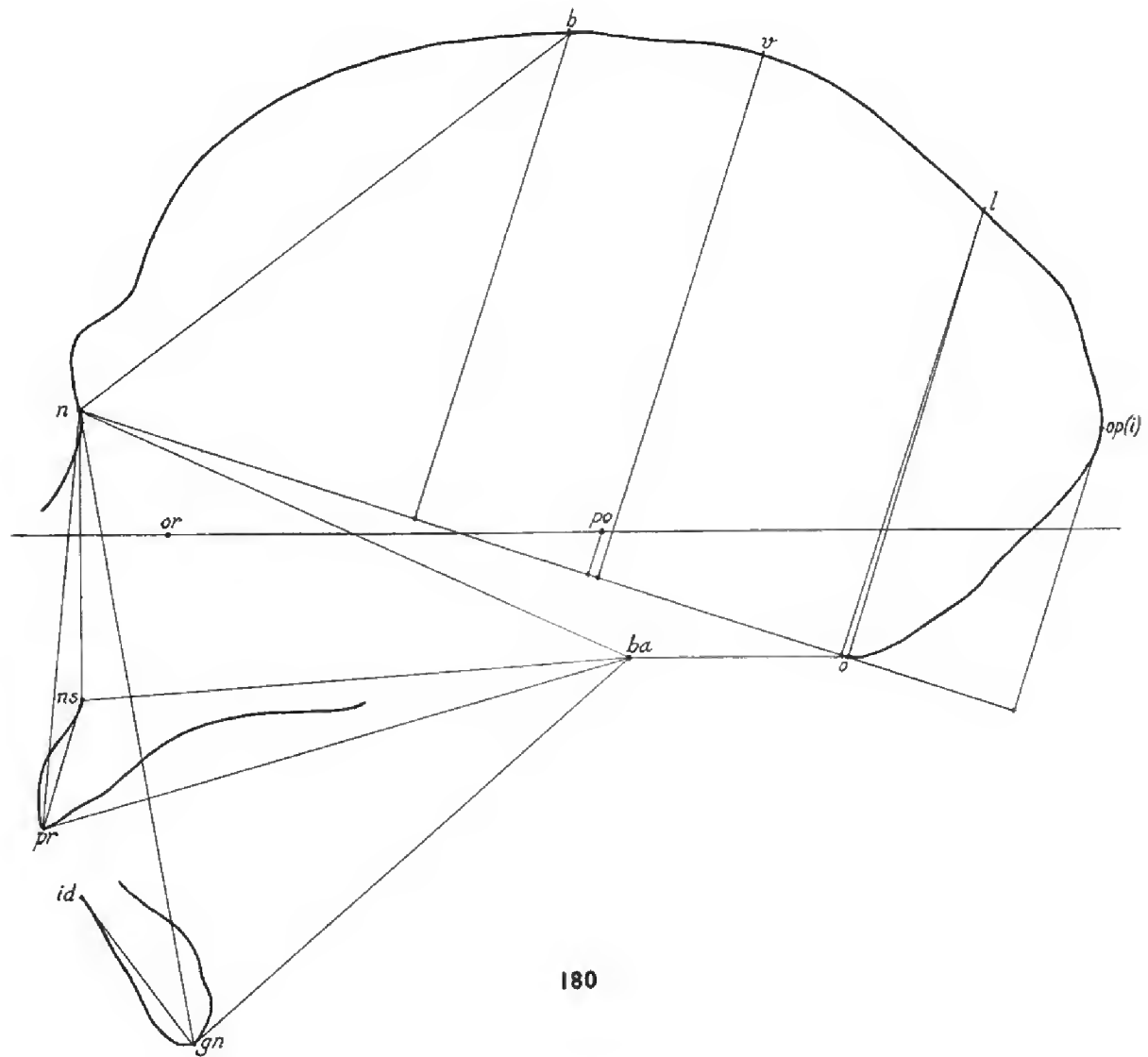
Fig. 181. Mid-sagittal craniogram of *Sinanthropus* Skull III—Skull of Locus E (Black). 1/1. The numbers refer to the numbers of the linear measurements and angles in Tables XIX and XX, respectively. Abbreviations see Figure 180; in addition: g, glabella; me, metopion; pai, porus acusticus internus; FH, Frankfort Horizontal.
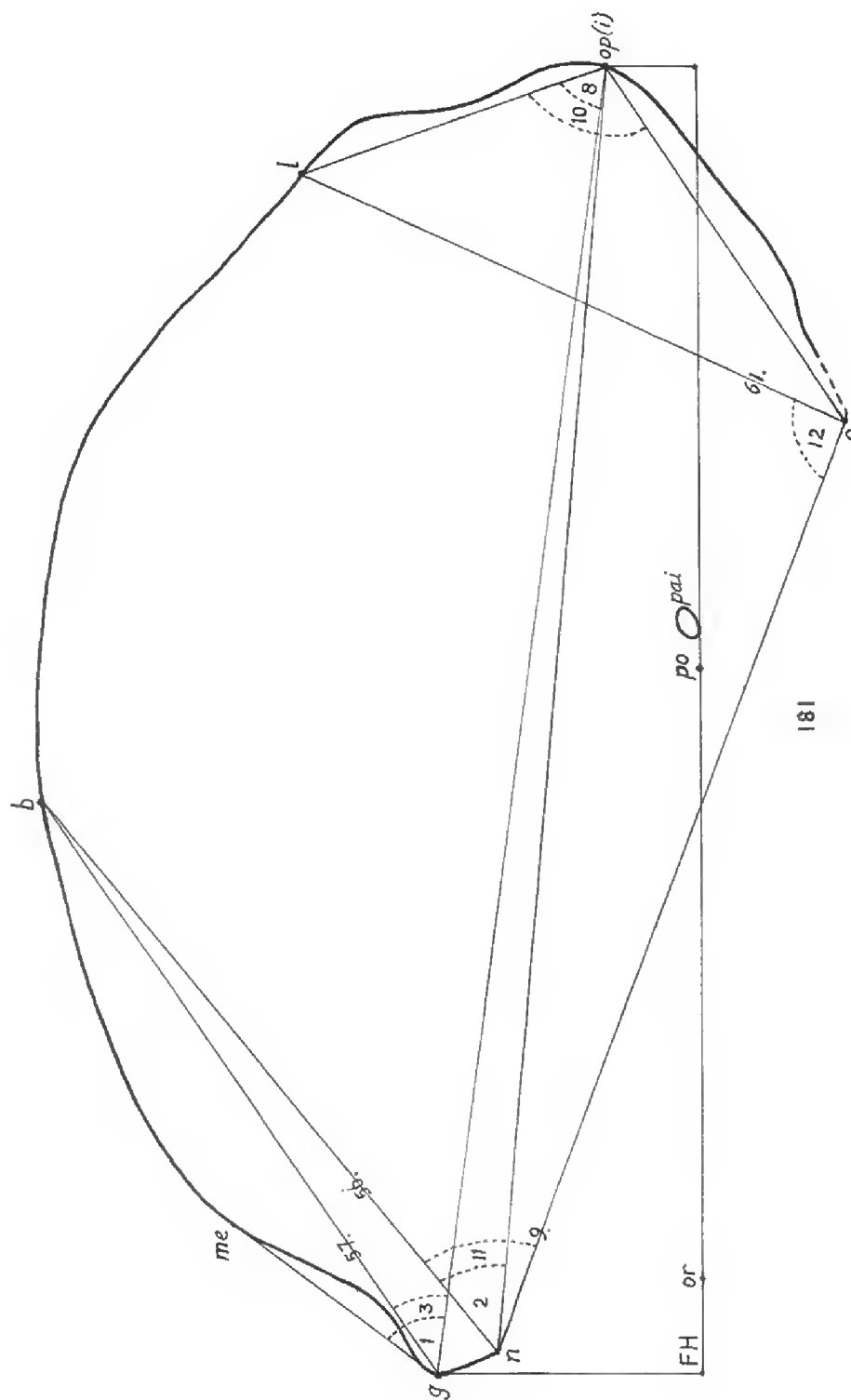
FIG. 182. Mid-sagittal craniogram of *Sinanthropus* Skull X—Skull I Locus L. 1/1. Abbreviations see Figures 180 and 181.
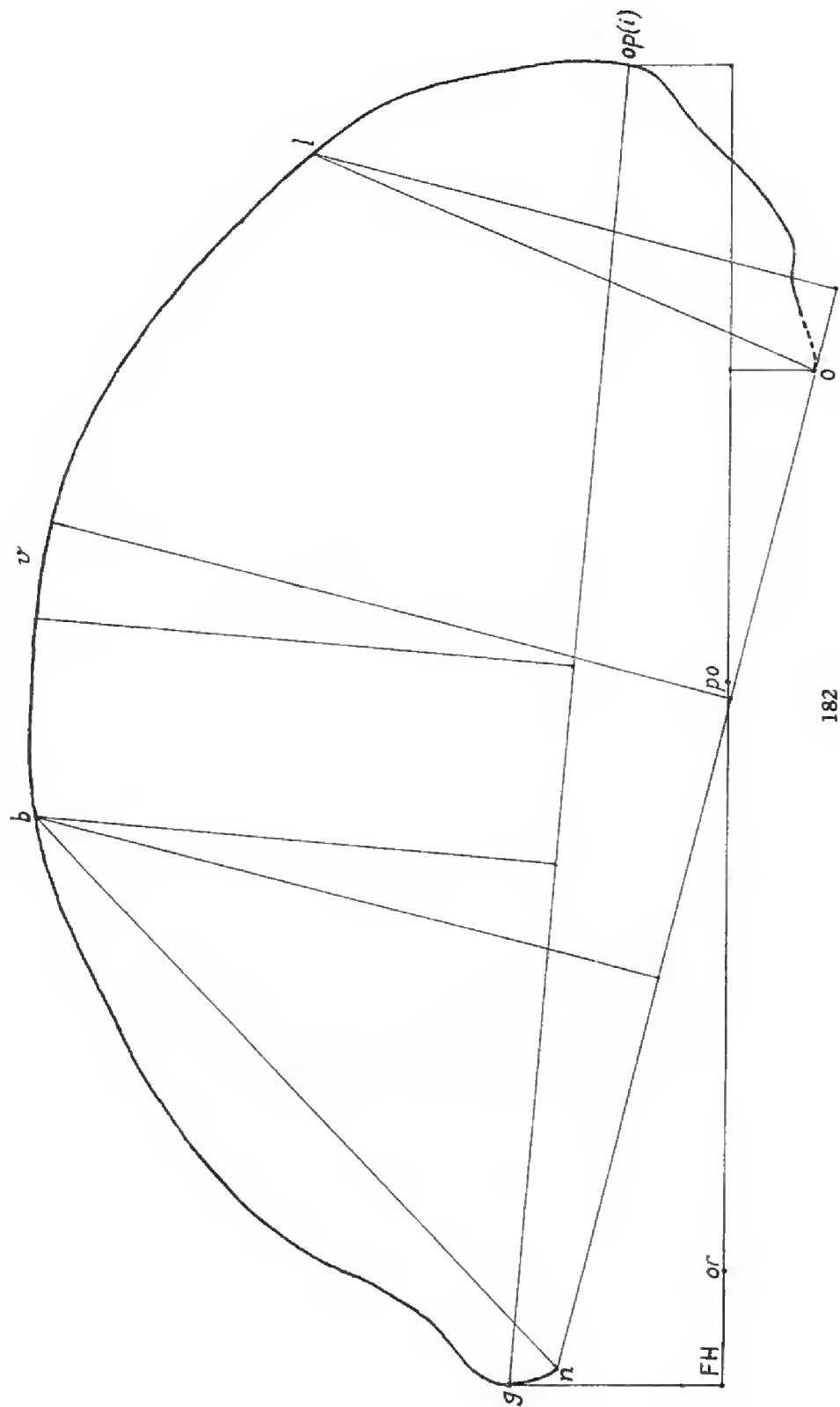
Fig. 183. Mid-sagittal craniogram of *Sinanthropus* Skull XI—Skull II Locus L. 1/1. The numbers refer to the number of the linear measurements and angles in Tables XIX and XX, respectively. Abbreviations see Figures 180 and 181.
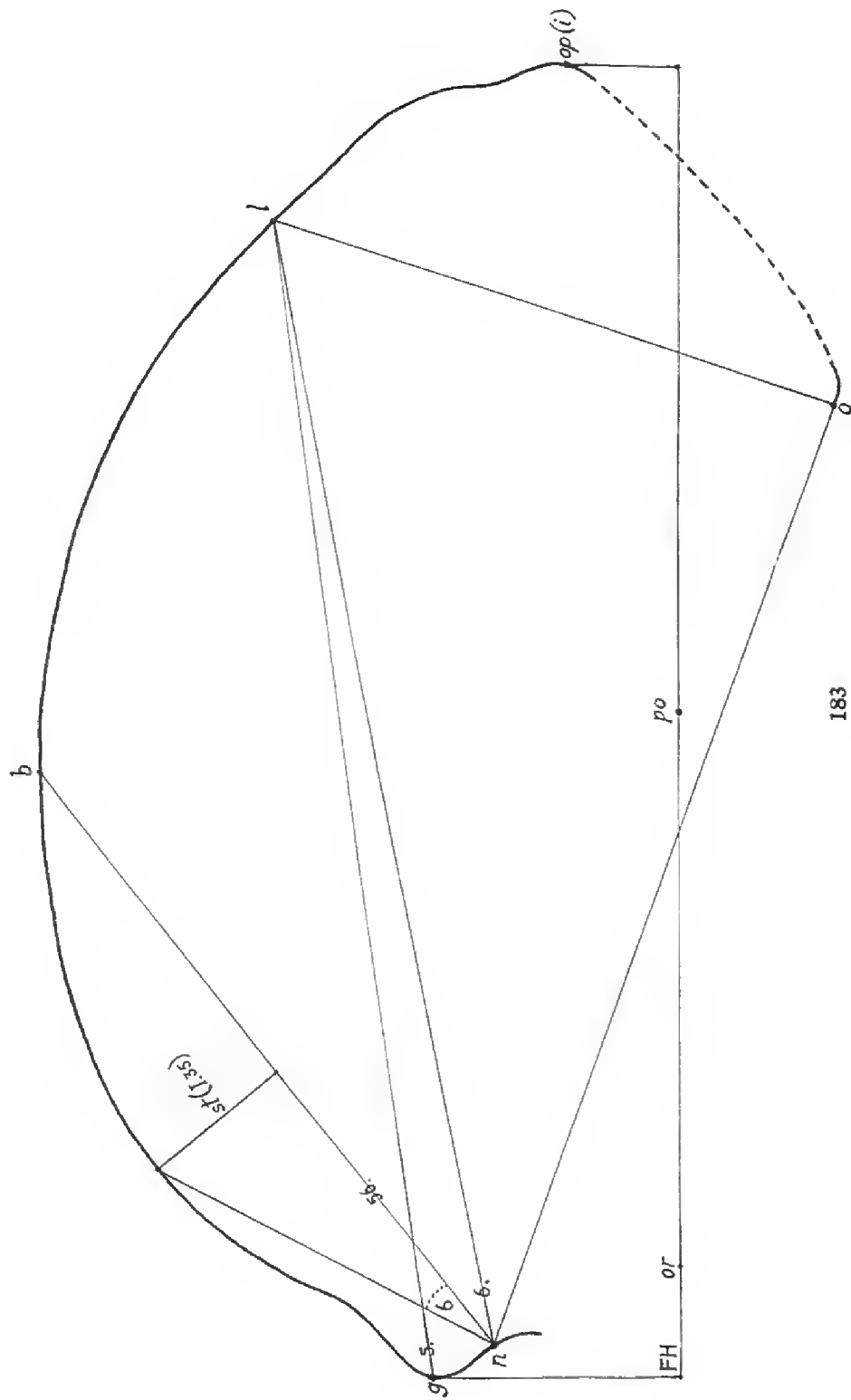
Fig. 184. Mid-sagittal craniogram of *Sinanthropus* Skull XII—Skull III Locus L. 1/1. The numbers refer to the numbers of the linear measurements and angles in Tables XIX and XX, respectively. Abbreviations see Figures 180 and 181; sg, supraglabellare.
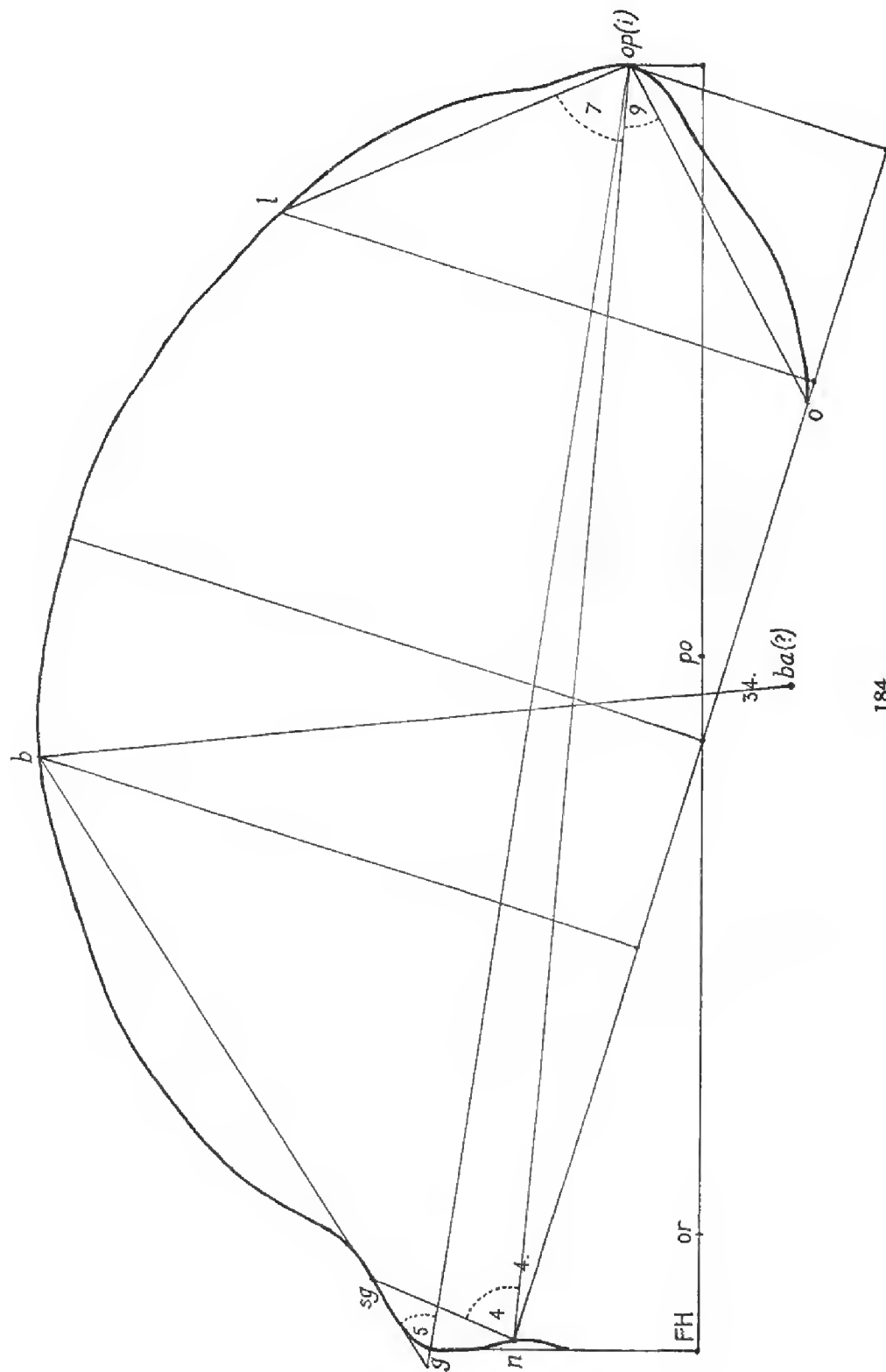
Fɪɢ. 185. Mid-sagittal craniogram of a male Australian aborigine (S.M.F. no. 1224). 1/2. Abbreviations see Figure 180; pr, prosthion.

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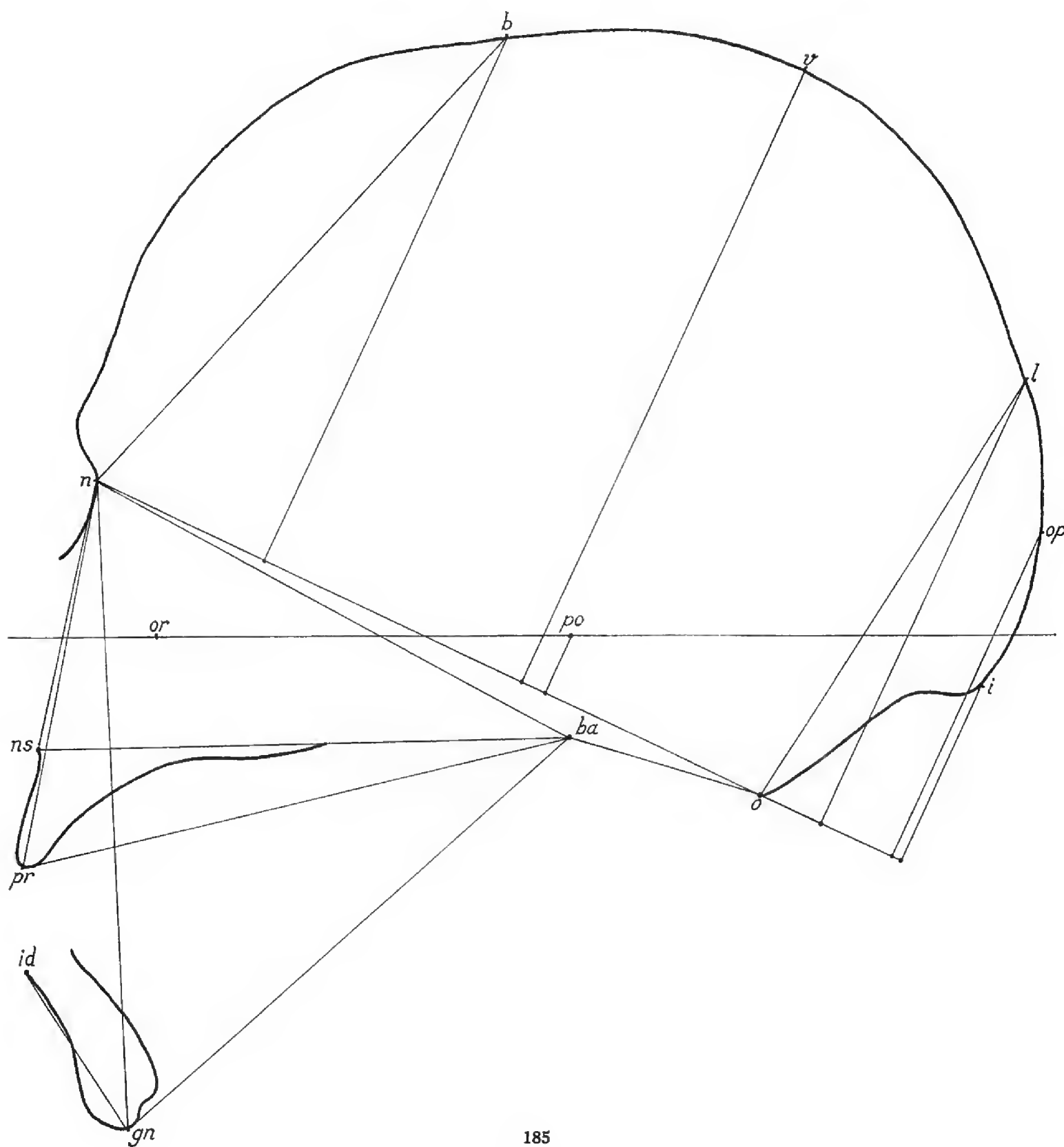
FIG. 186. Mid-sagittal craniogram of *Pithecanthropus* Skull II. 1/1. The numbers refer to the numbers of the linear measurements in Table XIX. Abbreviations see Figure 180.

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Fig. 187. Mid-sagittal craniogram of the *Homo soloensis* Skull V—(taken from cast). 1/1. Abbreviations see Figure 180.

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FIG. 193.   *Sinanthropus* Skull XI—Skull II Locus L.   The three coronal craniograms; see Figure 191.   1/2.

FIG. 194.   *Sinanthropus* Skull XII—Skull III Locus L.   The three coronal craniograms; see Figure 191.   1/2.

FIG. 195.   Interporial coronal craniograms superimposed on the po − po axis.   2/3.   Female gorilla (C.R.L.; no. 324) ———; *Pithecanthropus* Skull II ———; *Sinanthropus* Skull III − − − −; hyperdolichocranial Australian aborigine ♂ (S.M.F.; no. 1224; index 66.4) ••••••; hyperbrachycranial Austrian ♂ (C.R.L.; no. 14705; index 89.2) ······.   Abbreviations: lt, linea temporalis; po, porion; ss, sutura squamosa; ssg, sutura sagittalis.

FIG. 196.   Coronal craniograms (Interporial ——— and Posterior coronale − − − −) of the reconstructed *Pithecanthropus* Skull IV.   1/2.   Abbreviation: po, porion axis.

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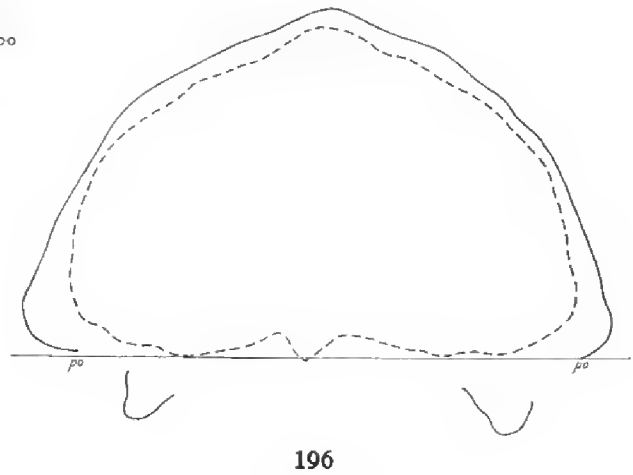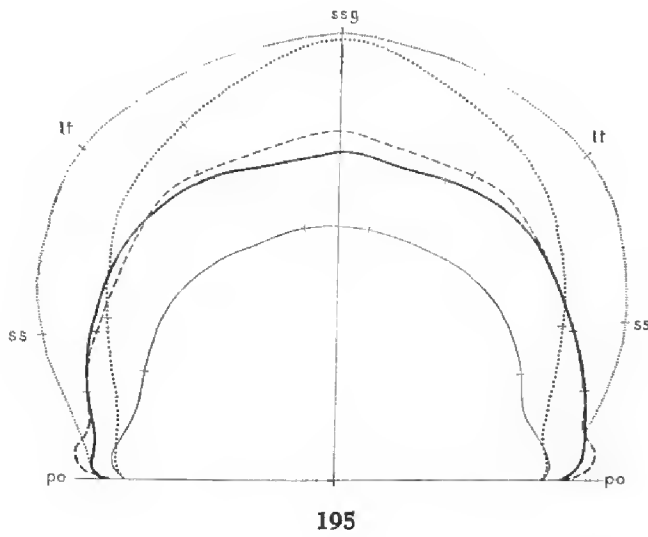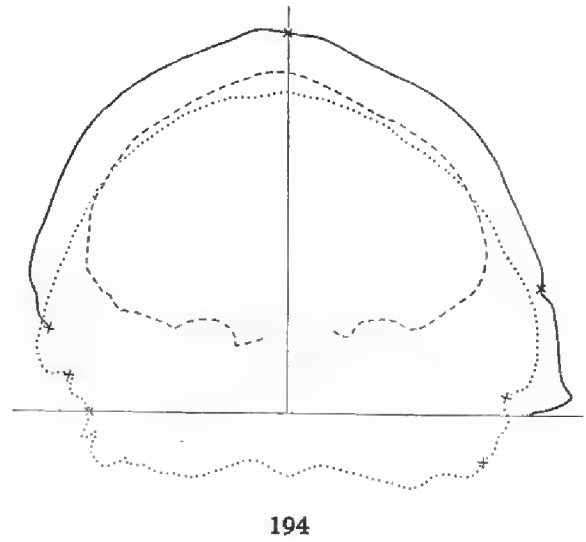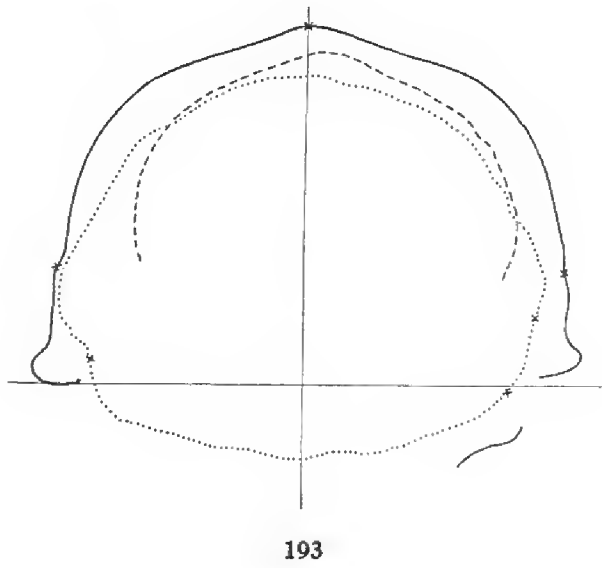
Fig. 197. *Homo soloensis* Skull VI. The three coronal craniograms (taken from cast). 1/2.

Fig. 198. *Homo soloensis* Skull XI. The three coronal craniograms (taken from cast). 1/2.

Fig. 199. Anterior coronal craniograms. Base line: interporial axis. 2/3. *Pithecanthropus* Skull II ————; *Sinanthropus* Skull III — — — —; *Homo soloensis* Skull V ————; Rhodesian Skull —·—·—·—·; hyperdolichocranial Australian aborigine ♂ (see Figure 195) oooo; hyperbrachycranial Austrian ♂ (see Fig. 195) ·······.

Fig. 200. Posterior coronal craniograms. Base line: interporial axis. 2/3. The same skulls as in Figure 199.

Fig. 201. Mid-sagittal craniogram of a *Saimiri sciureus*. 4/3. Abbreviations: b, bregma; ba, basion; g, glabella; i, inion; l, lambda; n, nasion; o, opisthion; op, opisthocranion; or, orbiculare; po, porion; pr, prosthion; FH, Frankfort Horizontal.

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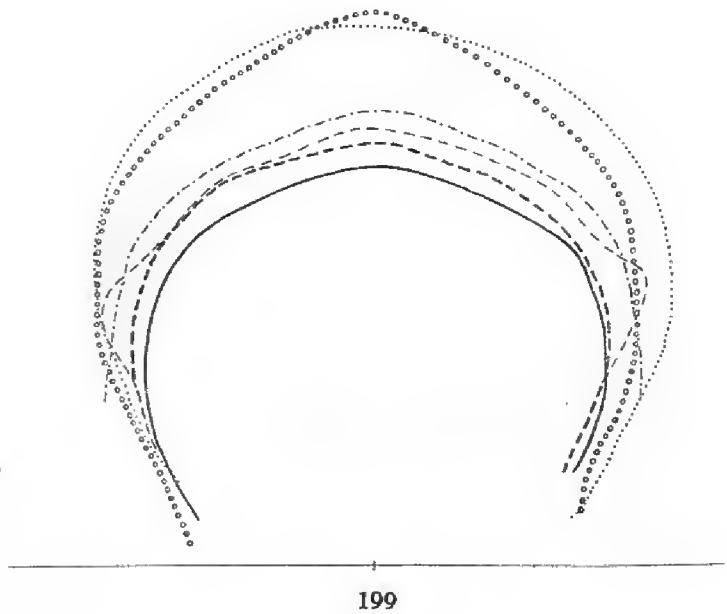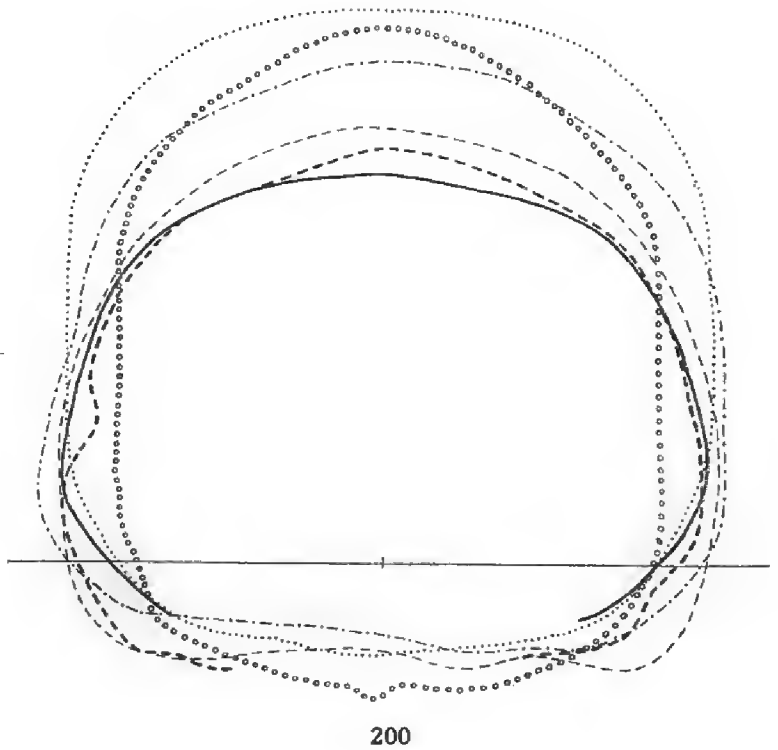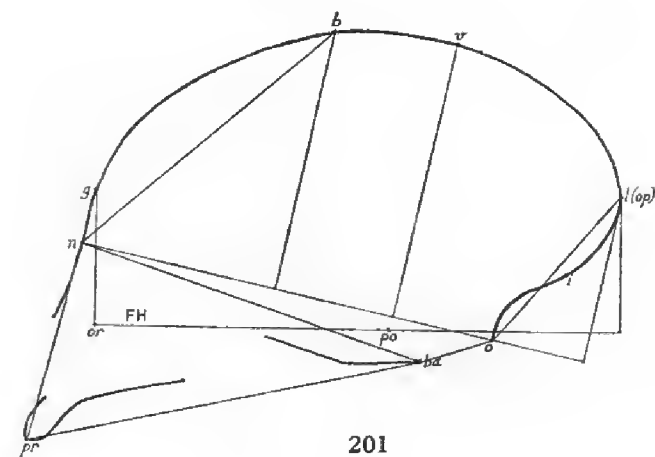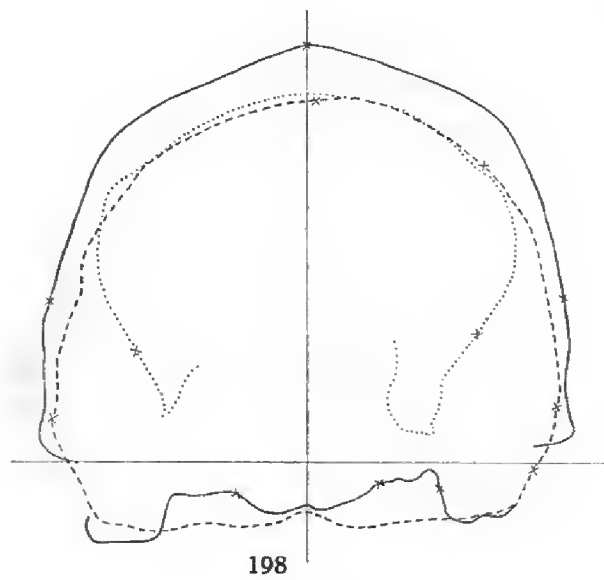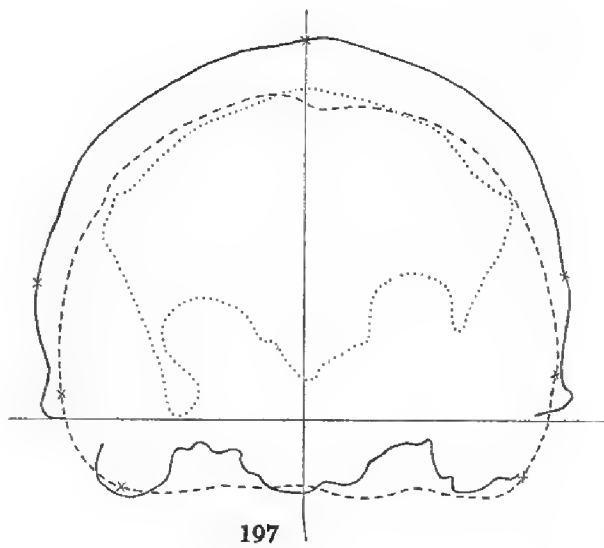
Fig. 202. Mid-sagittal index-diagram of the skulls of some platyrrhine monkeys. All measurements are related to the nasion-opisthion line which equals 100. 2/3. *Alouatta* ♂ —·—; *Lagothrix* ♂ and ♀ – – –; *Cebus* ♂ and ♀ ———; *Saimiri* ♂ ····. Abbreviations see Figure 201.

Fig. 203. Mid-sagittal craniograms of a male gorilla (A.M.N.H.; no. CA 507) and a male Austrian (A.M.N.H.; no. 4585) superimposed on the nasion-opisthion line. 1/2. Abbreviations see Figure 201. In addition: kl, klition; msp, margo superior pyramidis; ns, nasospinale; pai, porus acusticus internus.

202

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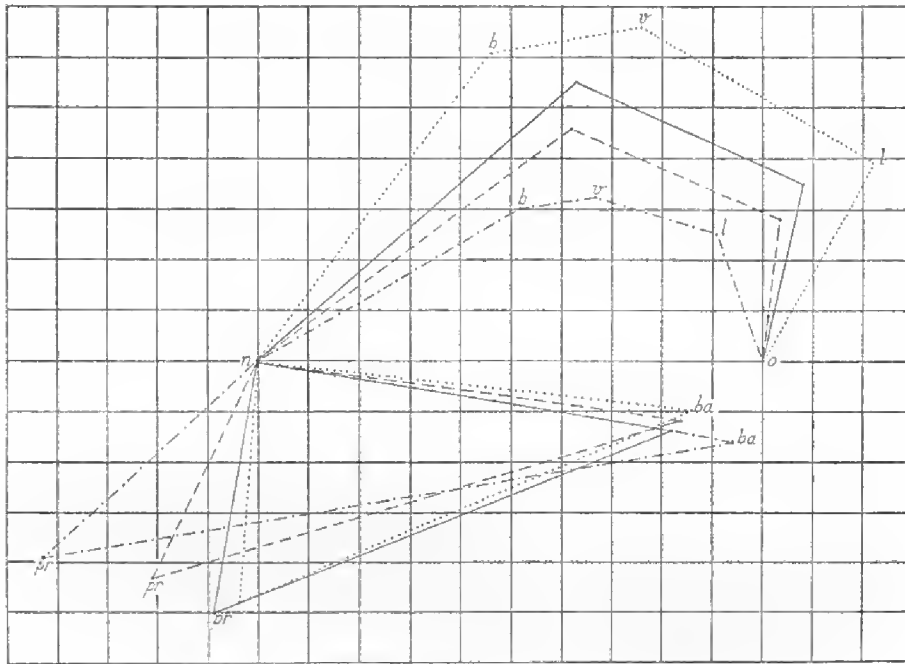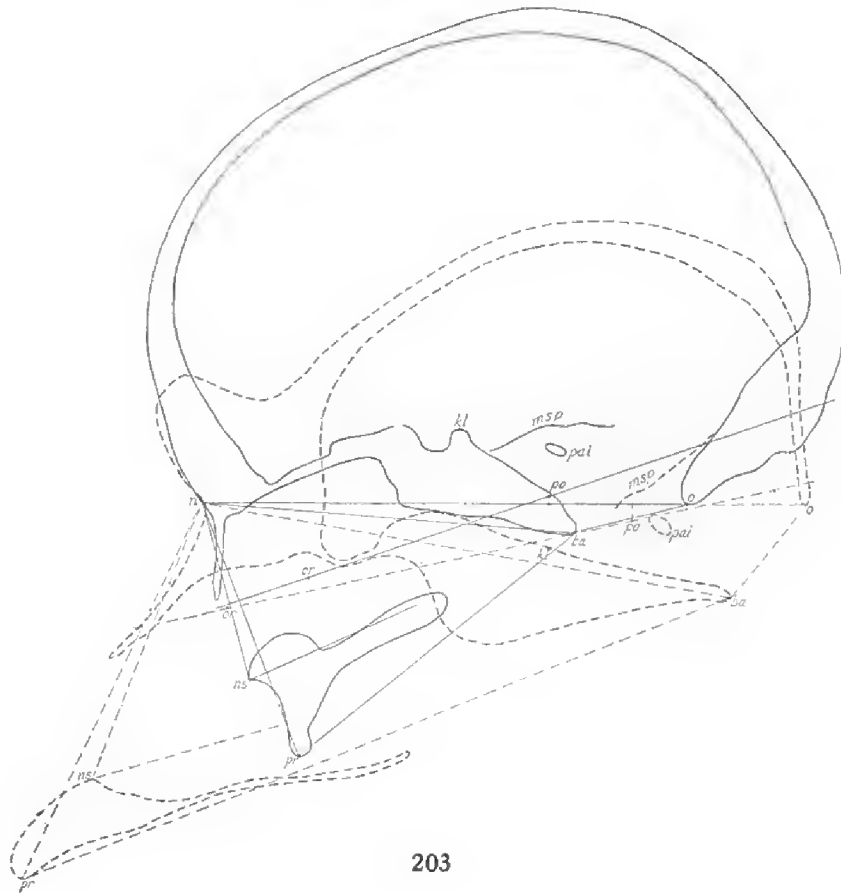
Fɪɢ. 204. Diagrams of the superior facial triangles (n-ba-pr) and the total facial triangles (n-ba-gn) of the reconstructed *Sinanthropus* Skull · · · ·; *Pithecanthropus* Skull IV –·–, average modern Man – – –, and average anthropoids ———. 2/3. All measurements are related to the nasion-basion line which equals 100. The line gnathion-incision (gn-i) indicates the direction of the mandibular front. The numbers are the actual measurements of the angles.

Fɪɢ. 205. Contours of the malar profile of the reconstructed *Sinanthropus* Skull indicating the vertical inclination-angle of the orbit (106°) and the malar profile angle (110°). 2/3. Abbreviations: fmo, frontomalare orbitale; fmt, frontomalare temporale; mf, maxillofrontale; n, nasion; ns, nasospinale; pr, prosthion; FH, Frankfort Horizontal; M¹ first molar; M² second molar.

Fɪɢ. 206. Mid-sagittal index-diagram of the calvariae of the average *Sinanthropus* ———, average anthropoids – – –, and average modern Man – –. All measurements are related to the nasion-opisthion line which equals 100. 2/3. The suprafacial triangle of *Sinanthropus* (———) is replaced by that of *Pithecanthropus* Skull IV. Abbreviations see Figure 201.

204

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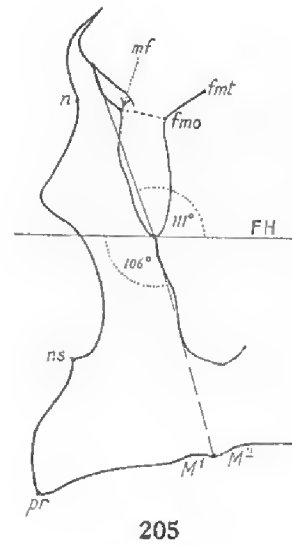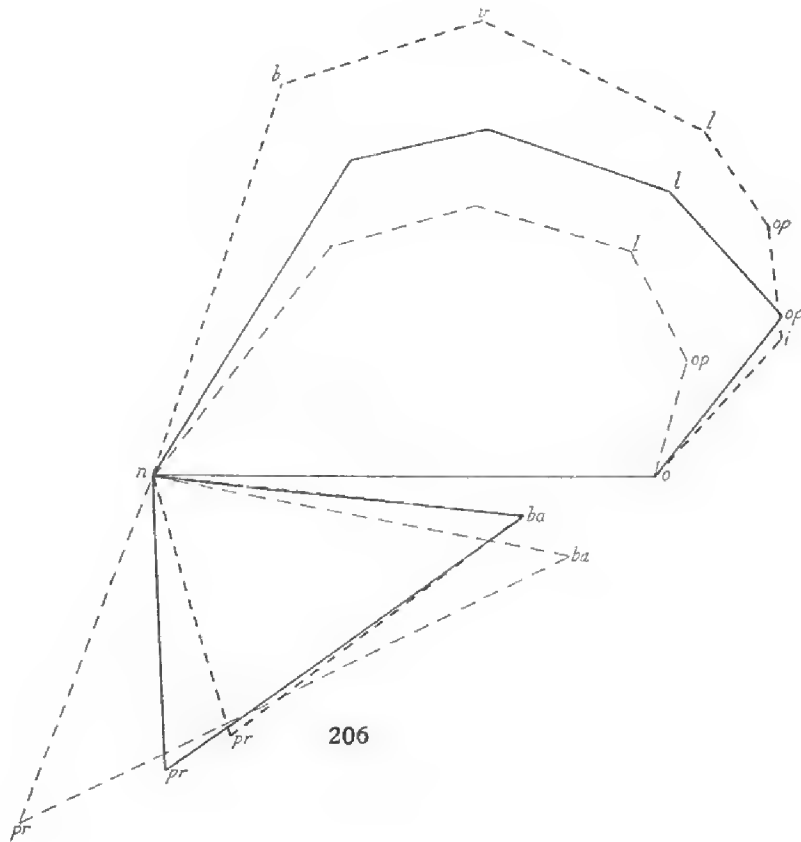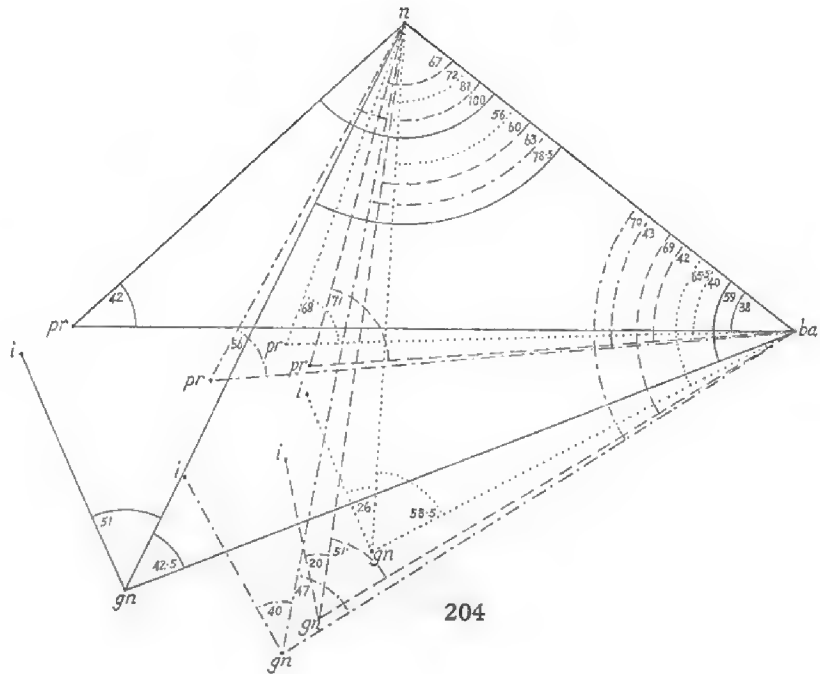
Fig. 207. *Sinanthropus* Skull X—Skull I Locus L. Left sagittal craniograms in Frankfort orientation at the three standard planes: Mid-sagittal ———; Mid-orbital – – –; Lateralorbital ····. 1/2. The point of contact of the vertical and horizontal lines indicates the position of the porion.

Fig. 208. *Sinanthropus* Skull XI—Skull II Locus L. 1/2. The same craniograms as in Figure 207.

Fig. 209. *Sinanthropus* Skull XII—Skull III Locus L. 1/2. The same craniograms as in Figure 207.

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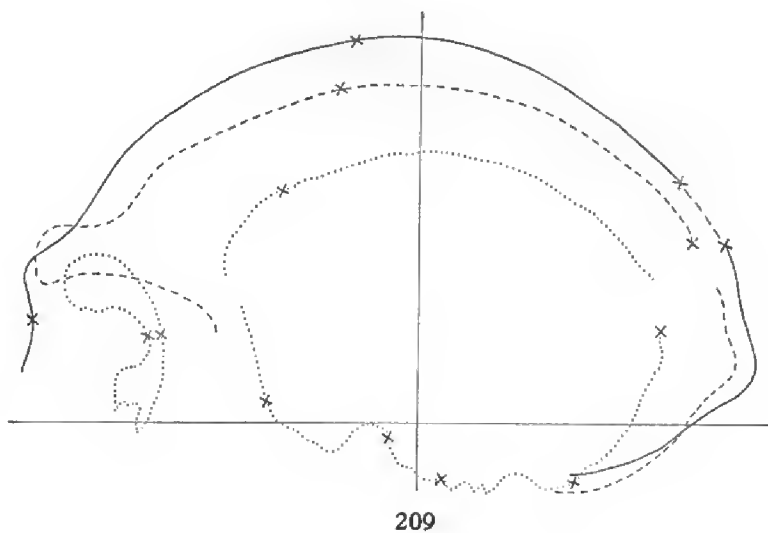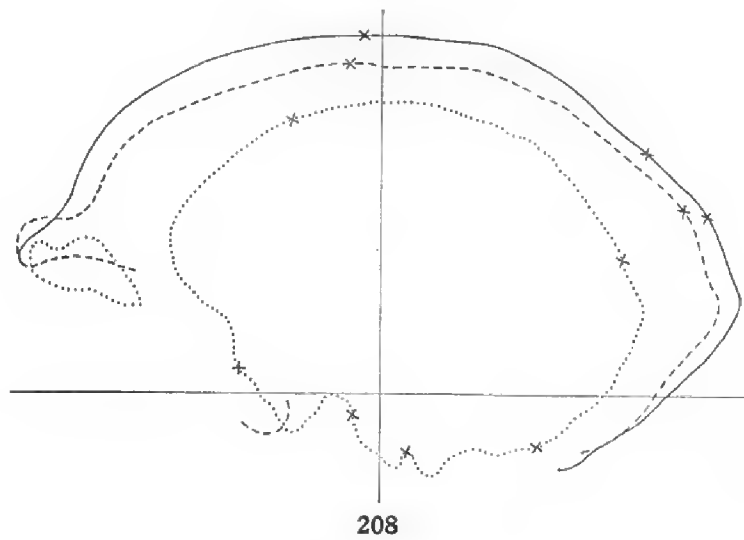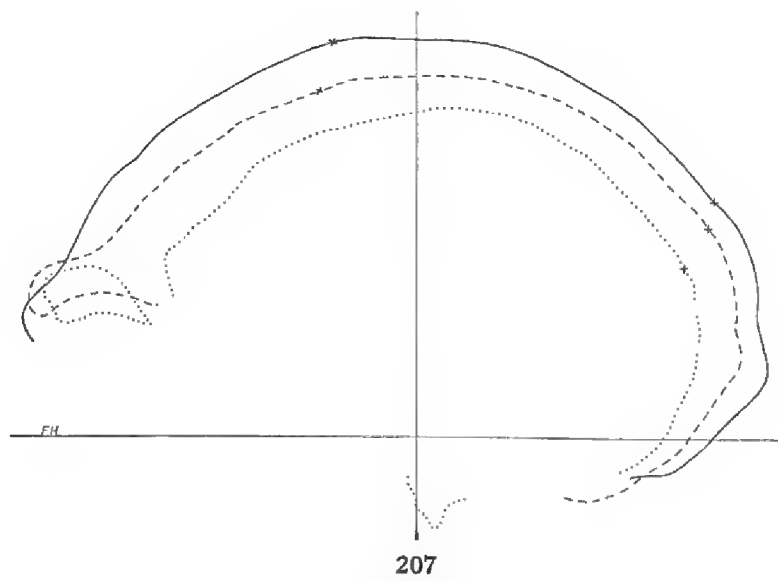
FIG. 210.   Reconstructed *Sinanthropus* Skull.   1/2.   The same craniograms as in Figure 207.

FIG. 211.   Hyperdolichocranial Australian aborigine ♂ (S.M.F., no. 1220; index 68.2).   Left sagittal craniograms as in Figure 207.   1/2.

FIG. 212.   Hyperbrachycranial Malayan ♀ (V.M.F.; Fl. I.; index 88.6).   Left sagittal craniograms as in Figure 207.   1/2.

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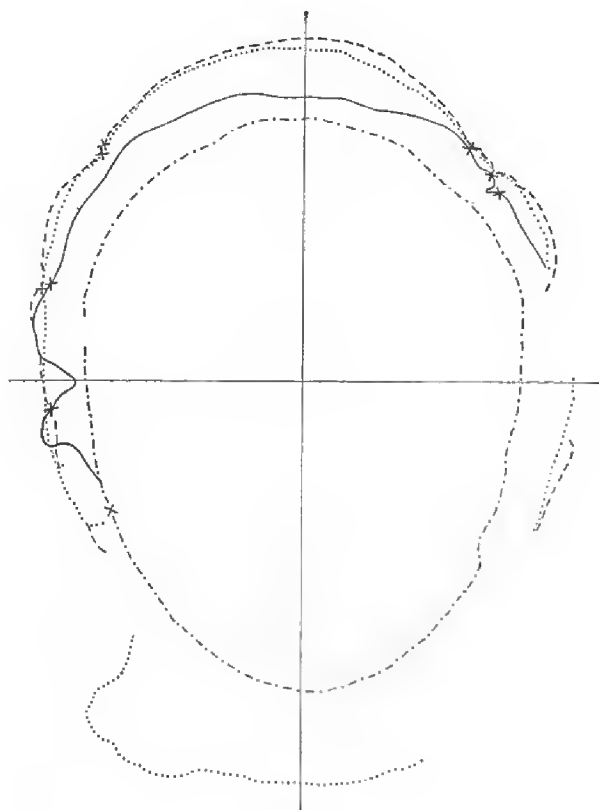
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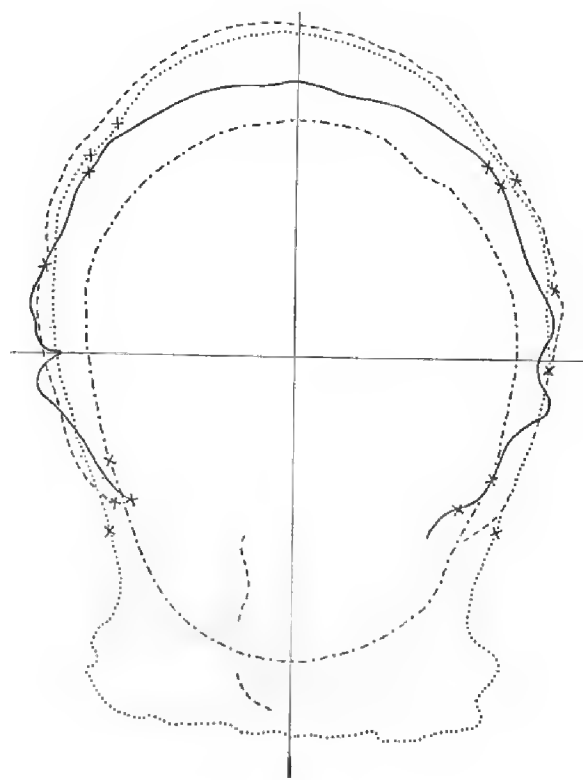
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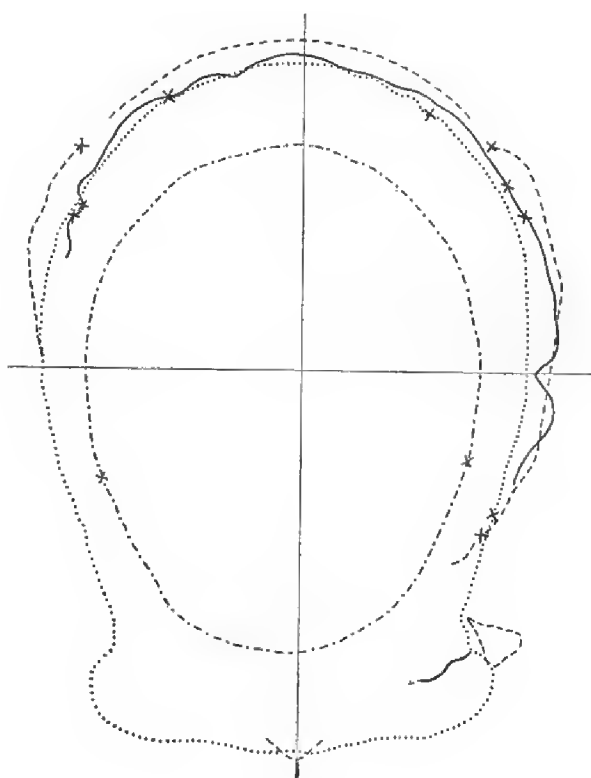
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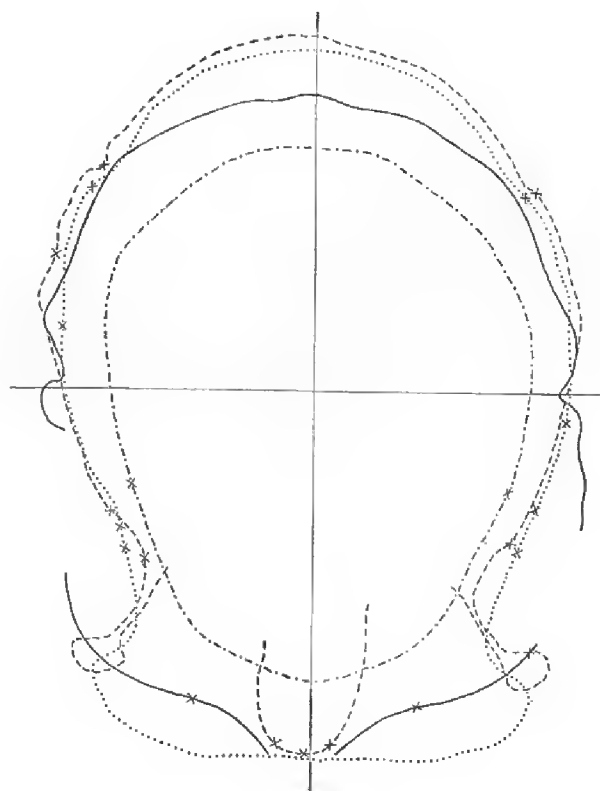
216

Fig. 217. *Homo soloensis* Skull VI. 1/2. Left sagittal craniograms as in Figure 207.

Fig. 218. *Homo soloensis* Skull XI. 1/2. Left sagittal craniograms as in Figure 207.

Fig. 219. Mid-sagittal craniograms of a female gorilla ———; *Pithecanthropus* Skull II ———; *Sinanthropus* Skull III – – –; hyperdolichocranial Australian aborigine •••; hyperbrachycranial European •••••• (cf. Figure 195). 2/3. The craniograms are superimposed on the Frankfort Horizontal and the porion. Abbreviations; b, bregma; g, glabella; i, inion; l, lambda; n, nasion; o, opisthion; or, orbiculare; po, porion.
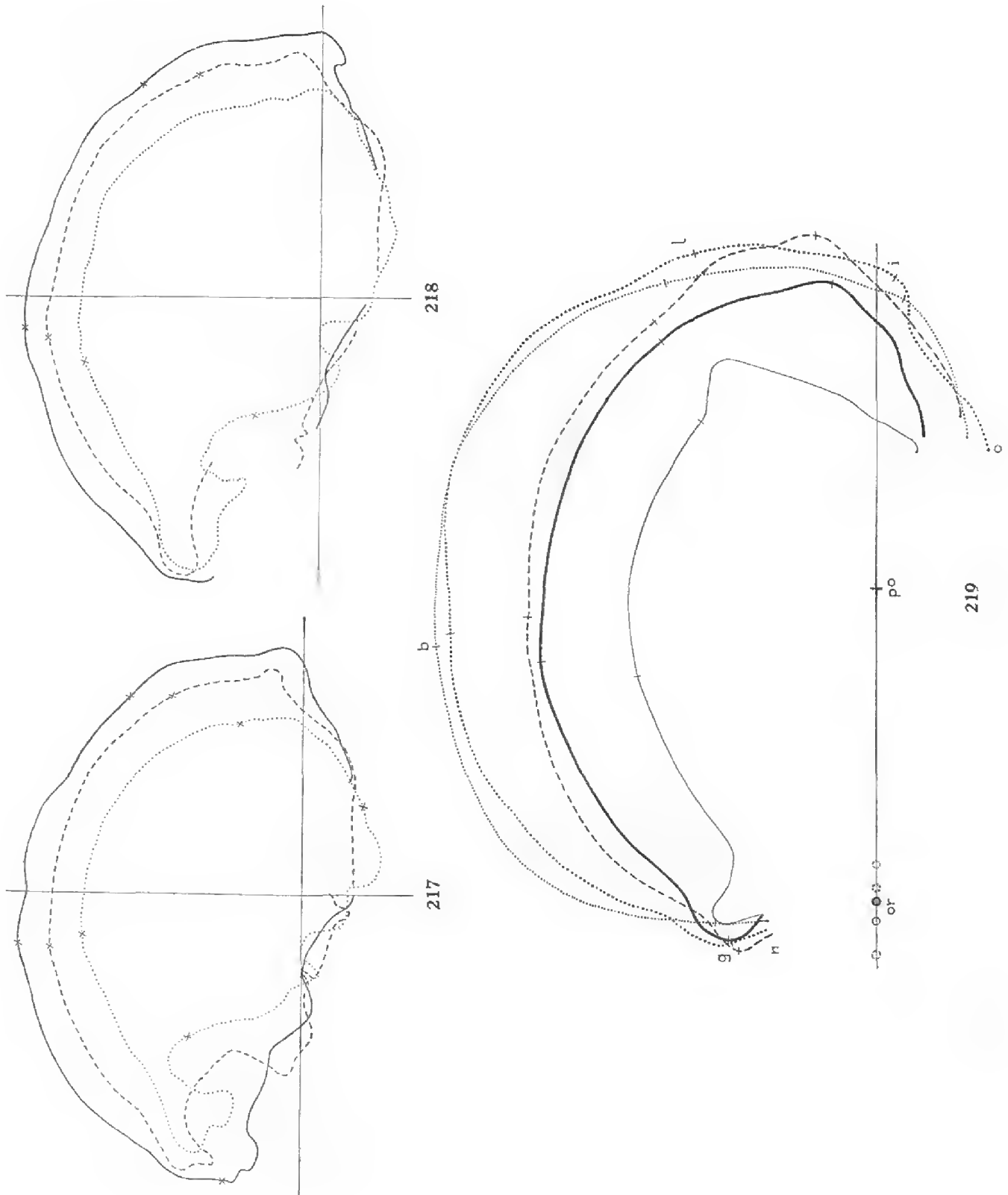
FIG. 220. Mid-sagittal craniograms marking the minimum and maximum limits of the expansion of the braincases
A, B of four *Sinanthropus* skulls ——————; five *Homo soloensis* skulls · · · · ·; six Neanderthal skulls –·–·–;
and sixteen modern skulls differing in size and form – – –. *Pithecanthropus* Skull II —————. 1/2.
The craniograms are superimposed on the nasion-opisthion line and the respective centers of this line.
The areas on which basion and porion fall have been marked. Fig. 220 A, minimum expansion; Fig.
220 B, maximum expansion. Abbreviations see Figure 219; in addition: ba, basion; op, opisthocranion.
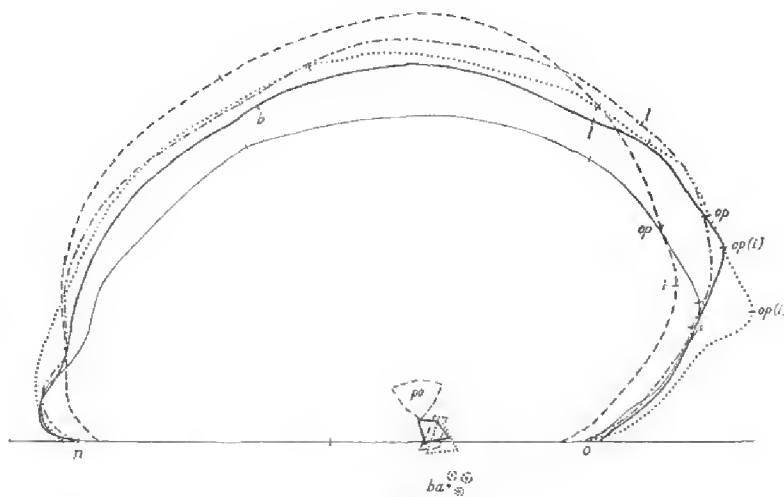
220A
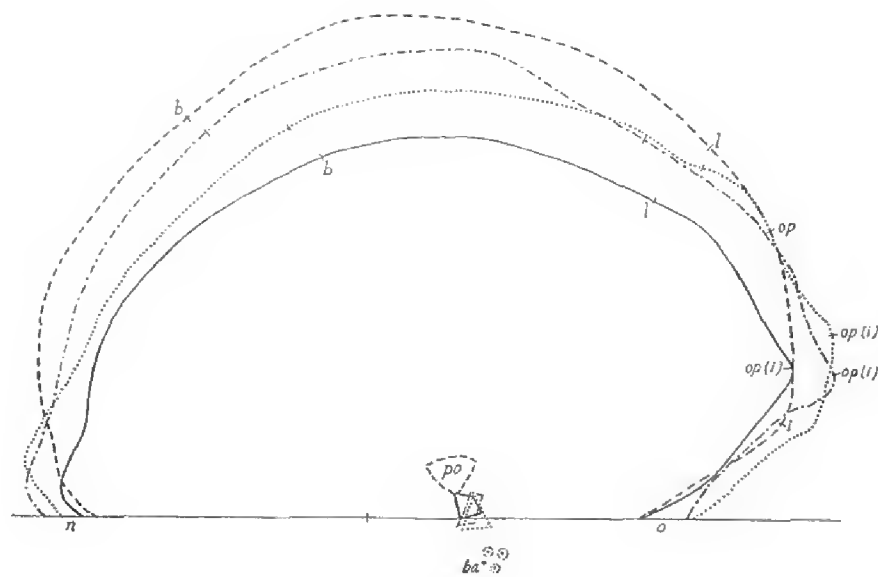
220B

Fig. 221. Mid-sagittal craniograms of the reconstructed skull of *Sinanthropus* ——— and a dolichocranial European of Nordic race – – –, superimposed from the nasion on the nasion-opisthion line. 3/4. The direction and length of the arrows indicate the course and the distance the landmarks have travelled during the evolution of the human skull from the *Sinanthropus* stage to that of modern Man. Abbreviations: b, bregma; ba, basion; gn, gnathion; i, inion; id, incision; kl, klition; l, lambda; n, nasion; no, nasospinale; o, opisthion; op, opisthocranion; or, orbiculare; po, porion; pr, prosthion; sta, staphylion; v, vertex.

221
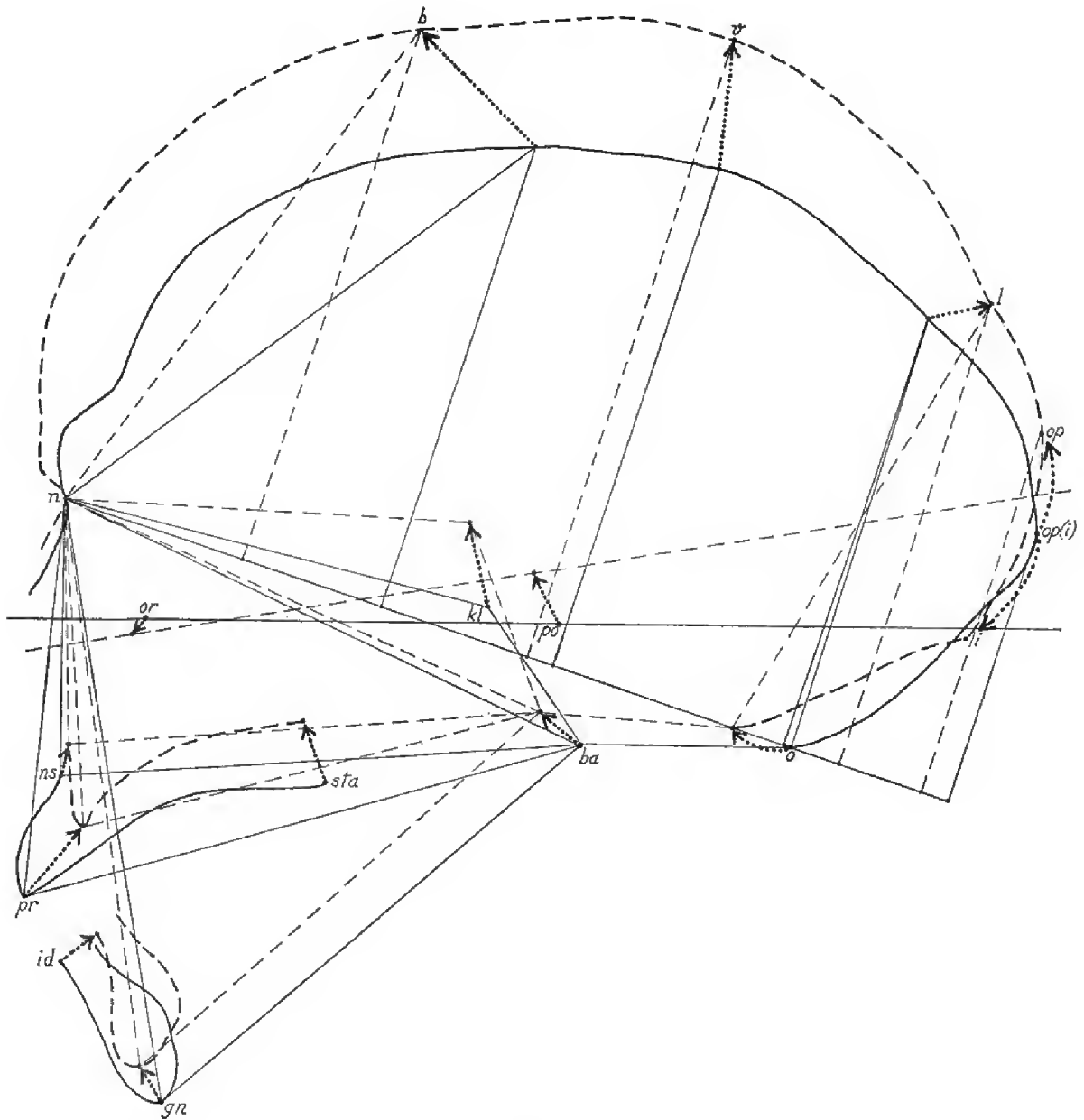
Fɪɢ. 222.   Mid-sagittal index-diagrams indicating the expansion of the braincase in the course of human evolution. All measurements are related to the nasion-opisthion line which equals 100.   2/3.   *Pithecanthropus* Skull II ———; *Sinanthropus* (average) ———; *Homo soloensis* (average) ······; Neanderthalians (average) —·—··—··—; modern Man (average) – – –.   Abbreviations see Figure 221.   FH, Frankfort Horizontal.

Fɪɢ. 223.   Mid-sagittal index-diagrams indicating form and size of the braincases of anthropoids (average) – – –; male *Saimiri* ———; *Sinanthropus* (average) ———, and modern Man (average) – – – –. 2/3.   All measurements are related to the nasion-opisthion line which equals 100.   Abbreviations see Figures 221 and 222.

Fɪɢ. 224.   Mid-sagittal index-diagrams indicating form and size of the braincases of anthropoids (average) – – –; modern Man (average) – –, and the average of microcephalics with a cranial capacity of less than 400 cc. ———.   2/3.   All measurements are related to the nasion-opisthion line which equals 100. Abbreviations see Figure 221.
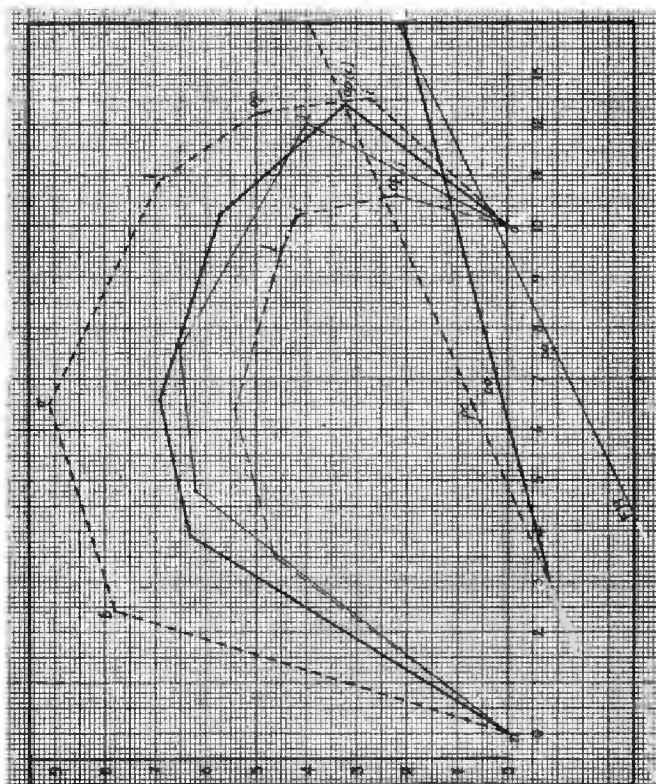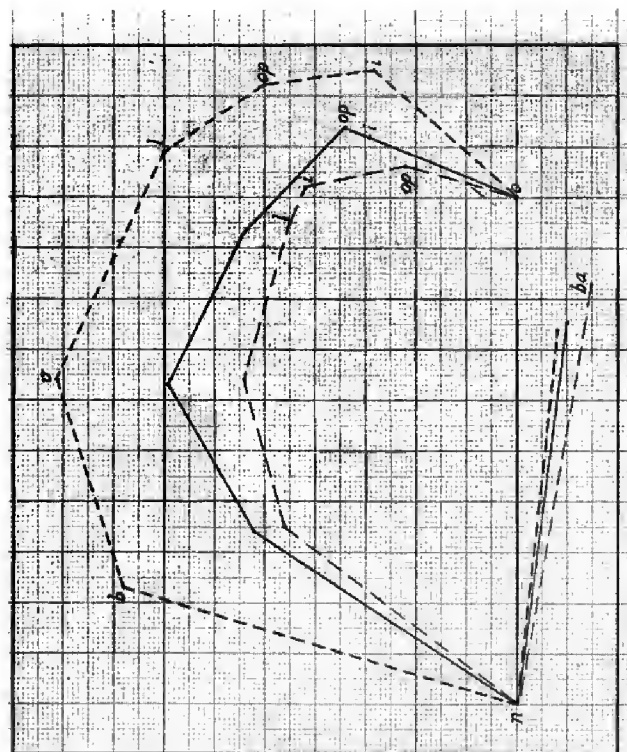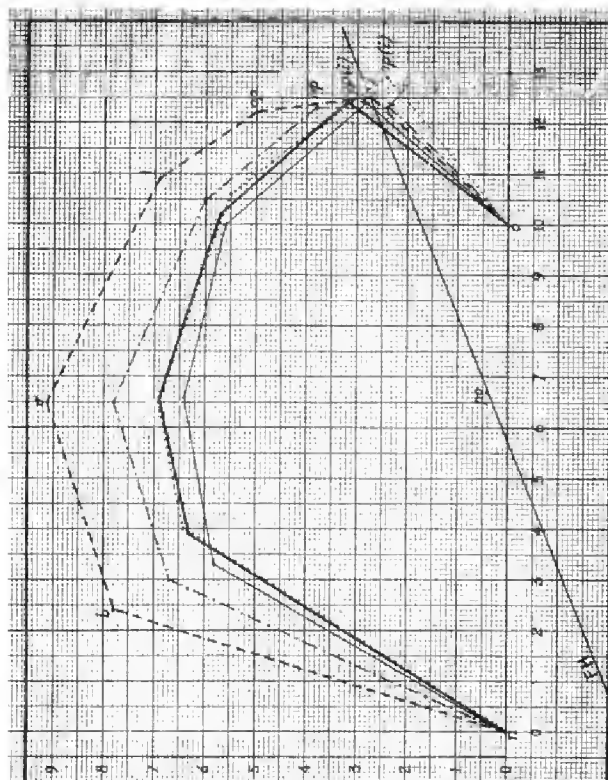
Fig. 225. Horizontal craniograms marking the minimum and maximum limits of the expansion of the braincases
A, B of the *Pithecanthropus* Skull I and II ————; four *Sinanthropus* Skulls (III, X, XI, XII) ————; five
Neanderthalians (*Homo soloensis* V, XI; Rhodesian; Tabūn I; Skhūl V) · · · · ·; and eight modern skulls
of various races – – –. The craniograms are superimposed on the centers of their greatest length.
The average porion position is indicated for each group. 1/2. Fig. 225 A, minimum expansion;
Fig. 225 B, maximum expansion.

Fig. 226. Interporial craniograms—orientation in Frankfort Horizontal—of *Pithecanthropus* Skull II ————;
Sinanthropus Skull III ————; hyperbrachycranial Austrian (length-breadth index 89.5) – –. 2/3.
Abbreviations: lt, linea temporalis; ss, sutura squamosa.

Fig. 227. Mid-sagittal craniograms of the three same skulls as in Figure 226, superimposed on the line of the
greatest length. The porion position of each skull is indicated by a point. 2/3. Abbreviations:
g, glabella; i, inion.
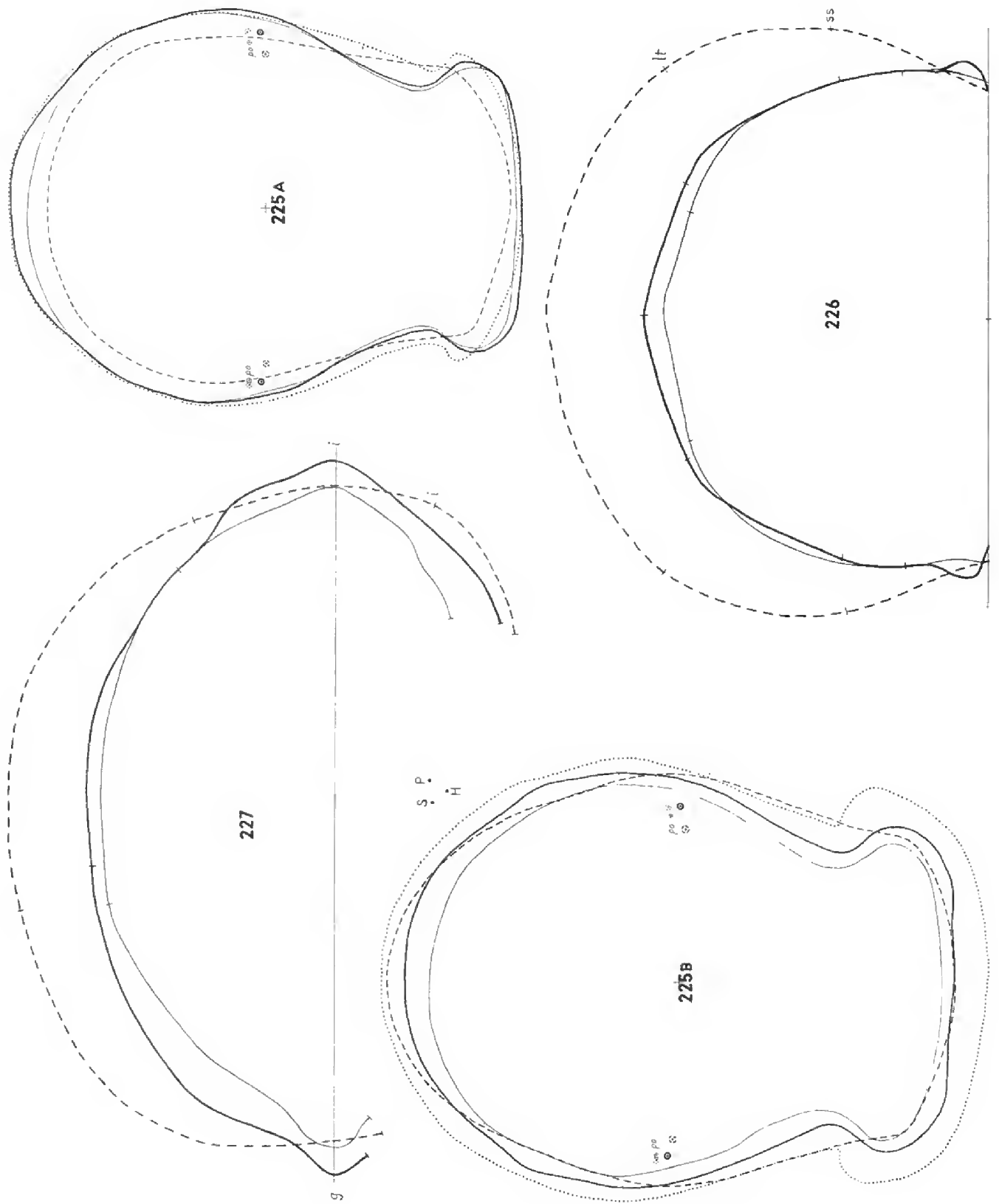
Fig. 228A. Skiagram of *Sinanthropus* Skull X. Photographed with the top toward the film. 1/1.

228A

FIG. 228B.   Skiagram of *Sinanthropus* Skull XI.   Photographed with the base toward the film.   1/1.

228B

FIG. 228C. Skiagram of *Sinanthropus* Skull XII. Photographed with the top toward the film. 1/1.

228C

FIG. 228D.   Skiagram of *Sinanthropus* Skull III.   Photographed with the base toward the film.   1/1.

228 D

Fig. 229. *Pithecanthropus* Skull IV after removal of the matrix. Occipital view. Drawing from the original. 1/1. Abbreviations: csg, crista sagittalis; ls, linea nuchae superior; sl, sutura lambdoidea; st, sulcus supratoralis; t, torus occipitalis; tp, torus angularis ossis parietalis.

Fig. 231. Scheme of the reinforcement-systems of the *Sinanthropus* skull in lateral view, indicated by vertical shading. 1/2.

Fig. 230. See Plate LXXVI.

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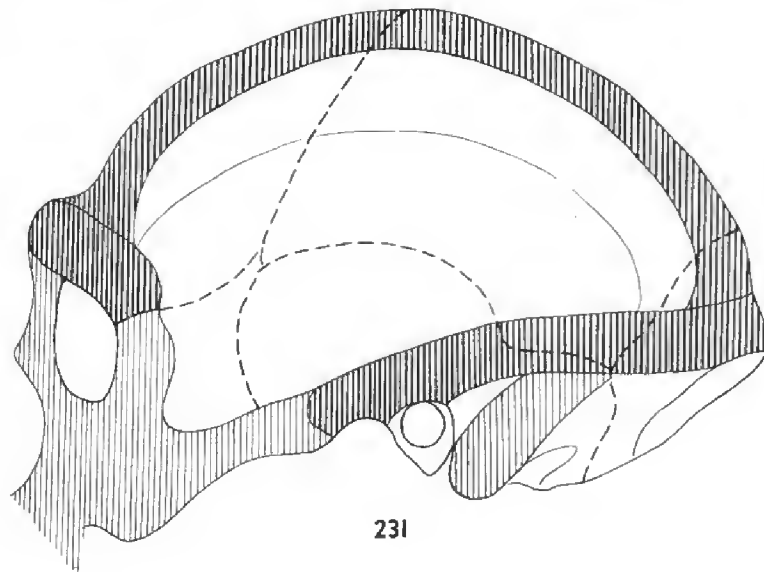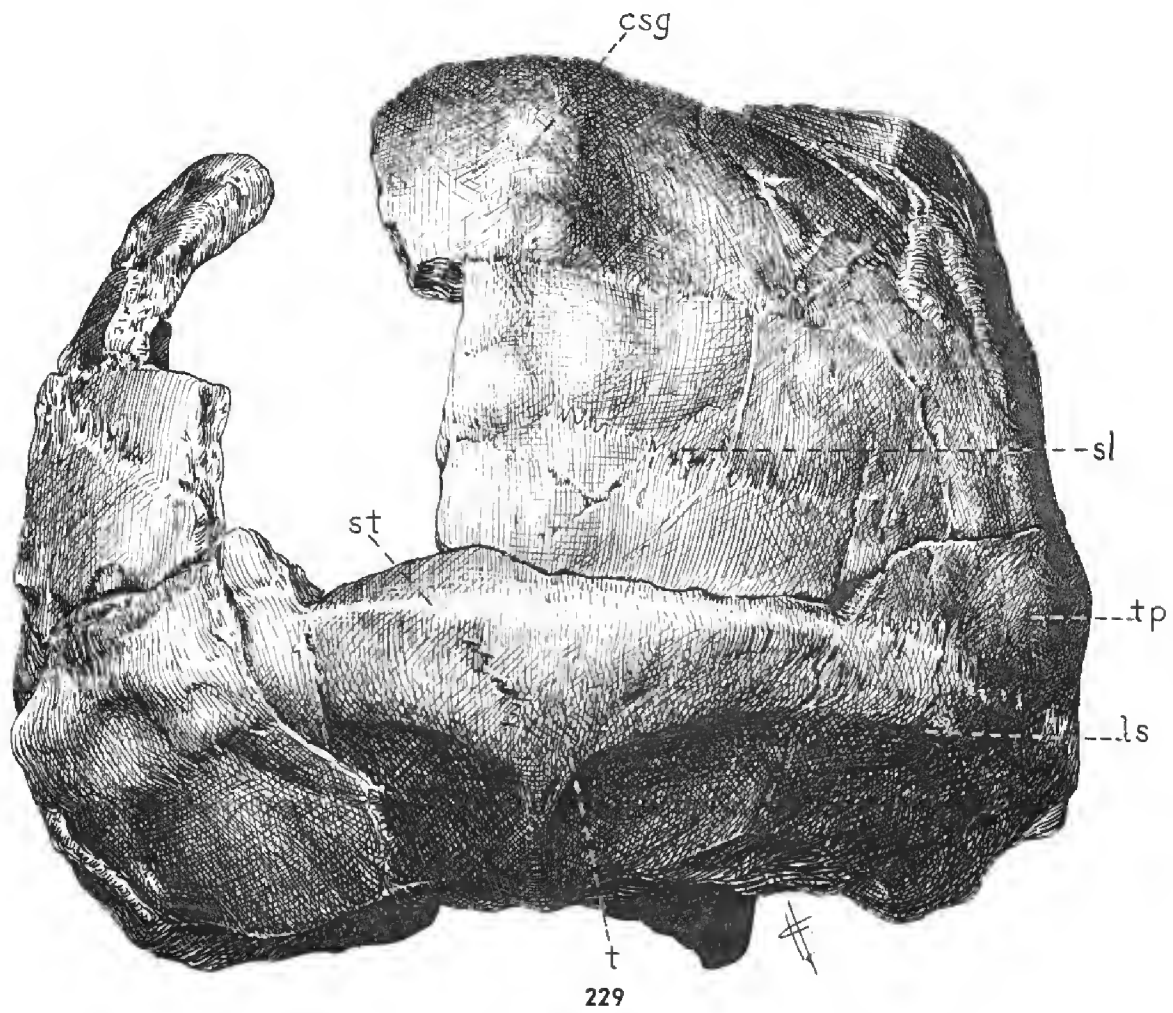
Fig. 230. *Pithecanthropus* Skull IV, after removal of the matrix.   Lateral view.   Drawing from the original.
1/1.   Abbreviations: cm, crista mastoidea; cs, crista supramastoidea; csg, crista sagittalis; im, incisura mastoidea; ls, linea nuchae superior; sl, sutura lambdoidea; st, sutura supratoralis; t, torus; tp, torus angularis ossis parietalis.

Fig. 232. Scheme of the reinforcement-systems of the *Sinanthropus* skull in basal view, indicated by horizontal shading.   1/2.

Fig. 231. See Plate LXXV.

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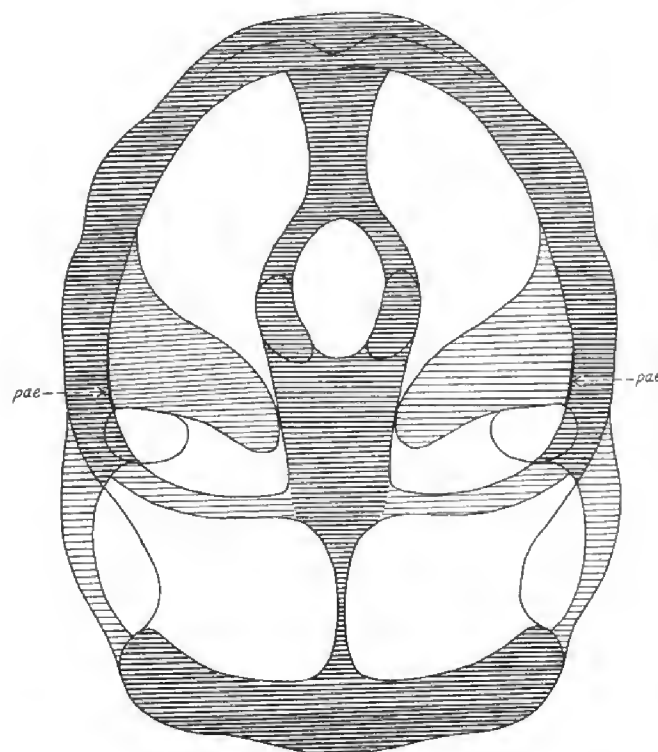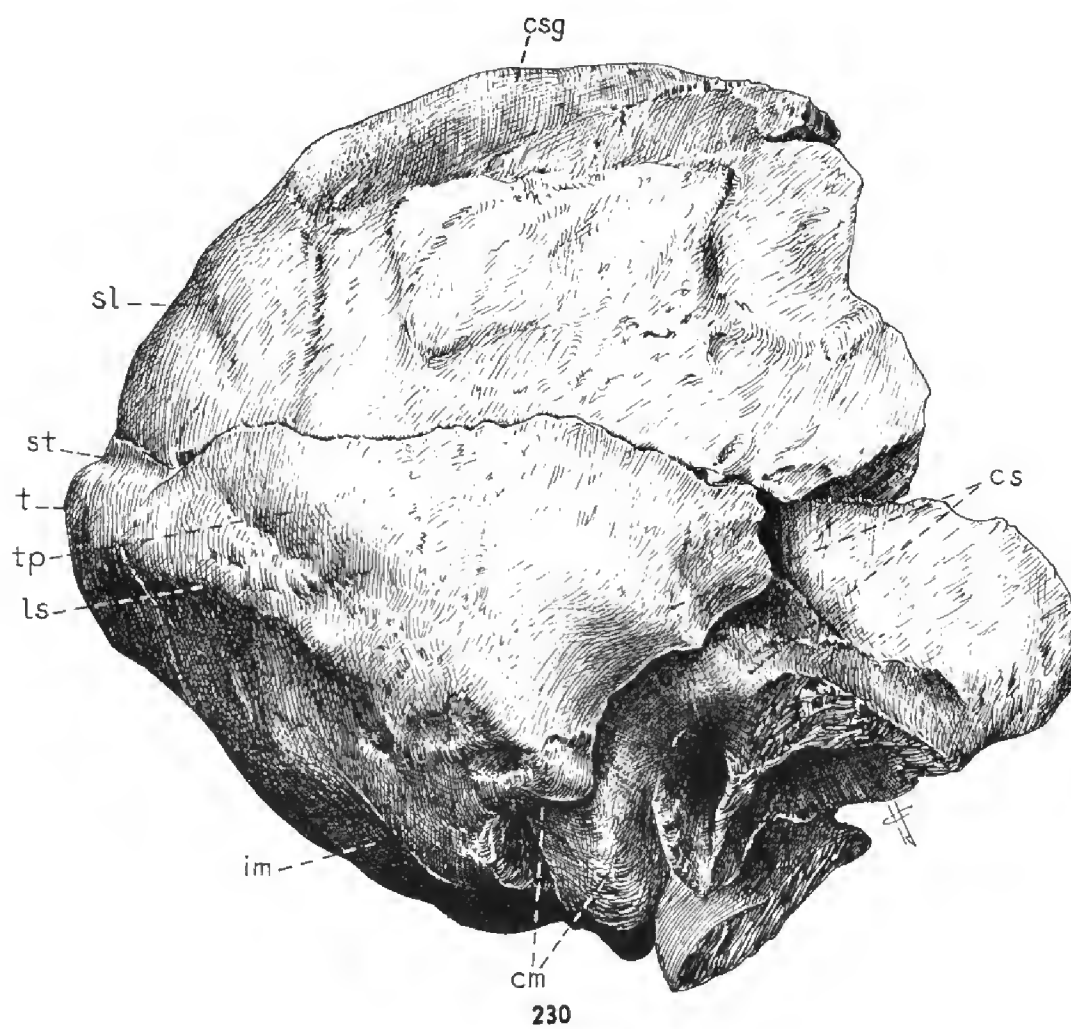
Fɪɢ. 233.   Skiagram of *Sinanthropus* Skull XII, photographed with the left side toward the film.   1/1.

FIG. 234.   Horizontal sections through the ophryon-inion plane of casts of *Sinanthropus* Skull III (A); *Sinanthropus* Skull XII (B) and *Pithecanthropus* Skull II (C), showing the thickness of the walls and the inner side of the base.   1/2.
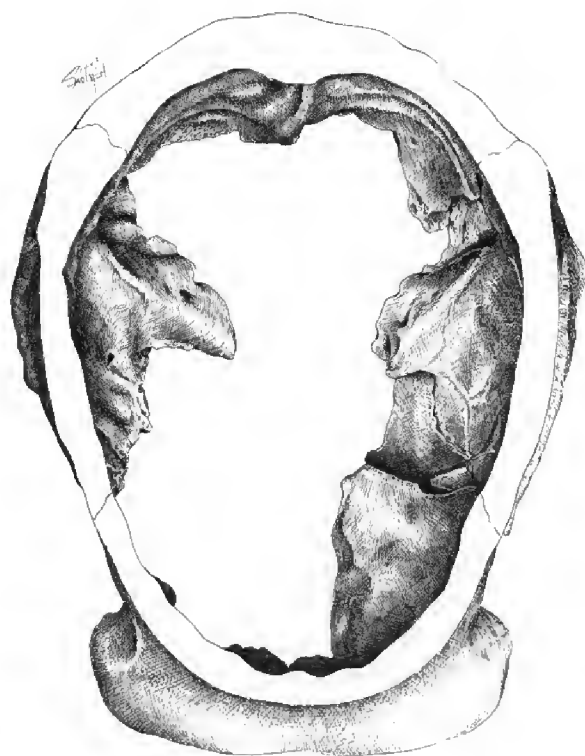
234 A
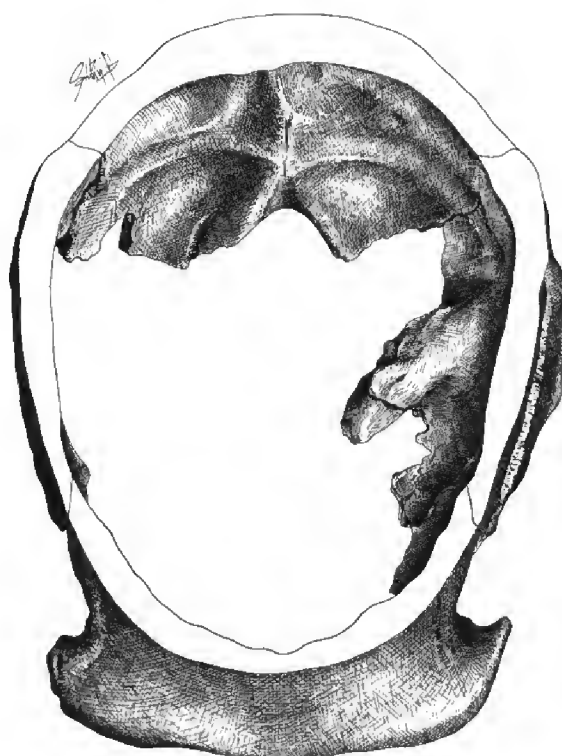
234 B

234 C

Fig. 235. Mid-sagittal craniograms of the outer and inner sides of *Sinanthropus* Skull III (A); *Sinanthropus* Skull X (B); *Sinanthropus* Skull XI (C); *Sinanthropus* Skull XII (D); *Pithecanthropus* Skull II (E); *Pithecanthropus* Skull IV (F); *Homo soloensis* Skull V (G). Showing the thickness of the walls. 1/4.

Fig. 236. Interporial craniograms of the outer and inner sides of *Sinanthropus* Skull X (A); *Sinanthropus* Skull XI (B); *Sinanthropus* Skull XII (C); *Homo soloensis* Skull V (D). Showing the thickness of the walls. 1/4.

Fig. 237. Coronal sections through the parietal bones in the center of the tuber, showing the thickness of the walls. 1/4. *Sinanthropus* Skull X (A); *Sinanthropus* Skull XI (B); *Sinanthropus* Skull XII (C); *Pithecanthropus* Skull III—juvenile—(D).

Fig. 238. Horizontal sections approximately through the ophryoninion plane, showing the thickness of the walls. 1/4. Male Australian aborigine (A)—prehistoric North Chinese (Province Shensi)—with unusually thick cranial bones (B); female gorilla after Schwalbe, 1899 (C).

Fig. 239. Skiagrams of the temporal bones of *Sinanthropus* Skull III, photographed with the inner side toward the film. 1/1. Right bone (A); left bone (B).

235

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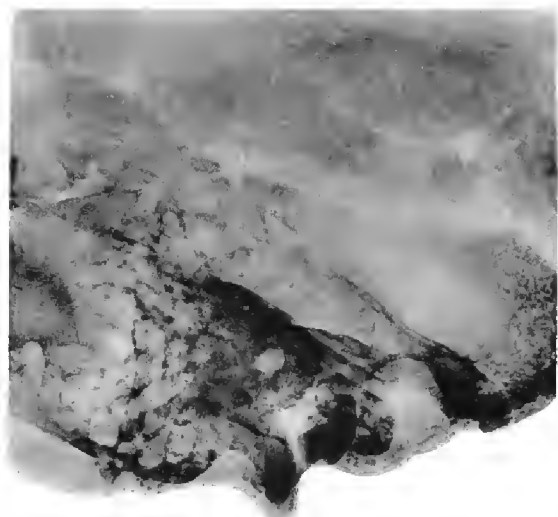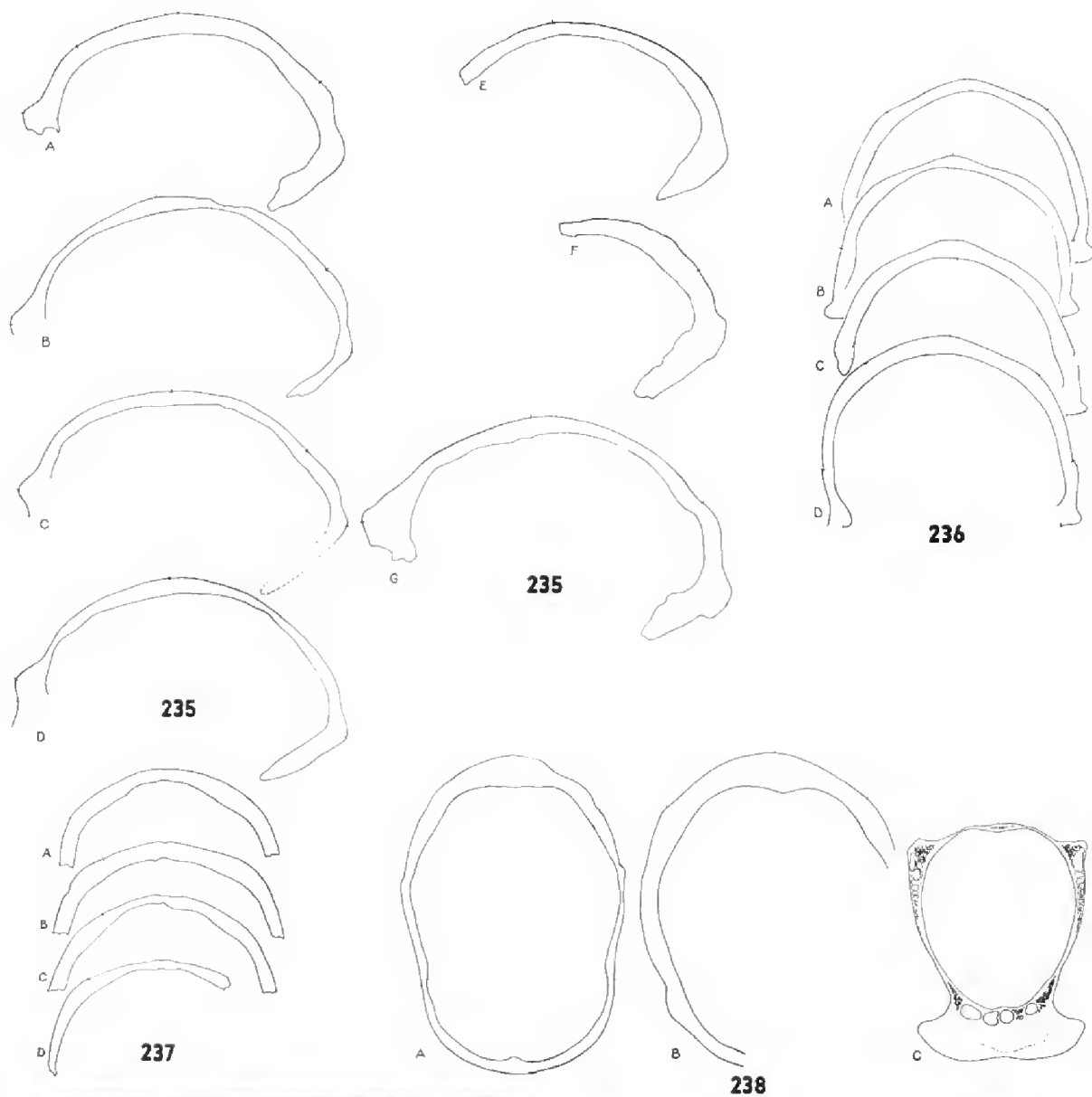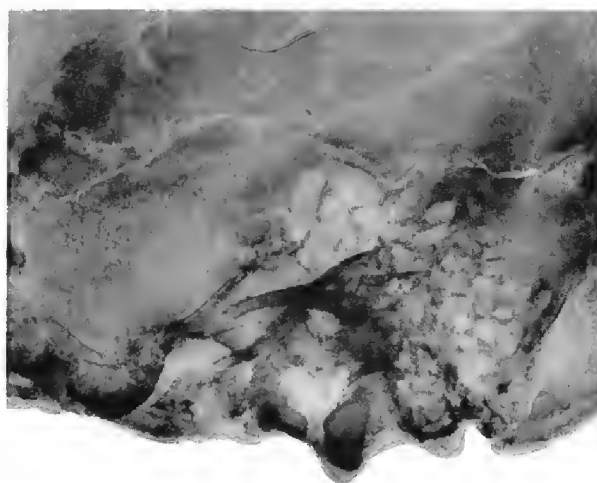
239A   239B

FIG. 240. Skiagrams of the temporal bones of *Sinanthropus* Skull XI, photographed with the inner side toward the film. 1/1. Right bone (A); left bone (B).

FIG. 241. Skiagrams of the left temporal bones of *Sinanthropus* Skull X (A) and *Sinanthropus* Skull XII (B), photographed with the inner side toward the film. 1/1.

FIG. 242. Skiagram of the left temporal bone of *Sinanthropus* Skull V; photographed with the inner side toward the film. 1/1.

240A

240B

241A

241B

242

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FIG. 247. *Pithecanthropus* Skull III. Occipital view. Photograph from the original (see also Figure 261). 2/3. Abbreviation: do, obelion depression.

FIG. 248. *Pithecanthropus* Skull IV. Maxilla in basal view, after removal of the matrix. Photograph from the original. 2/3.

FIG. 249. Horizontal section through Level 25 of Locality of Choukoutien. The squares have been traced with white lines on the level of the floor and designated by letters and numbers to facilitate the location of each find. Each square measures four squaremetres. The sites where the *Sinanthropus* Skull X (Locus L 1, 1), *Sinanthropus* Skull XI (Locus L 1, 2) and *Sinanthropus* Skull XII (Locus L 2, 3) have been recovered, are marked by special signs.

FIG. 250. Horizontal section through Level 24 of Locality 1 of Choukoutien. Explanation see Figure 249. The site where *Sinanthropus* Mandible K is found is marked by the small number 27 in the square I, O.

247

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250

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253

A   B   C   D

256
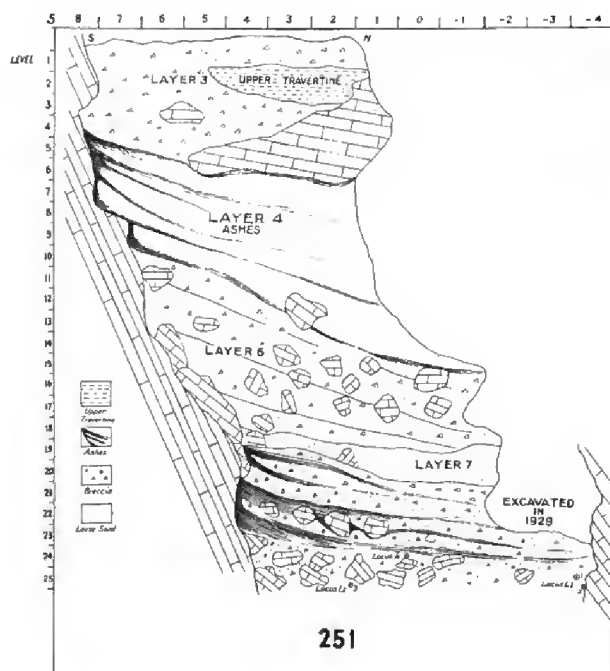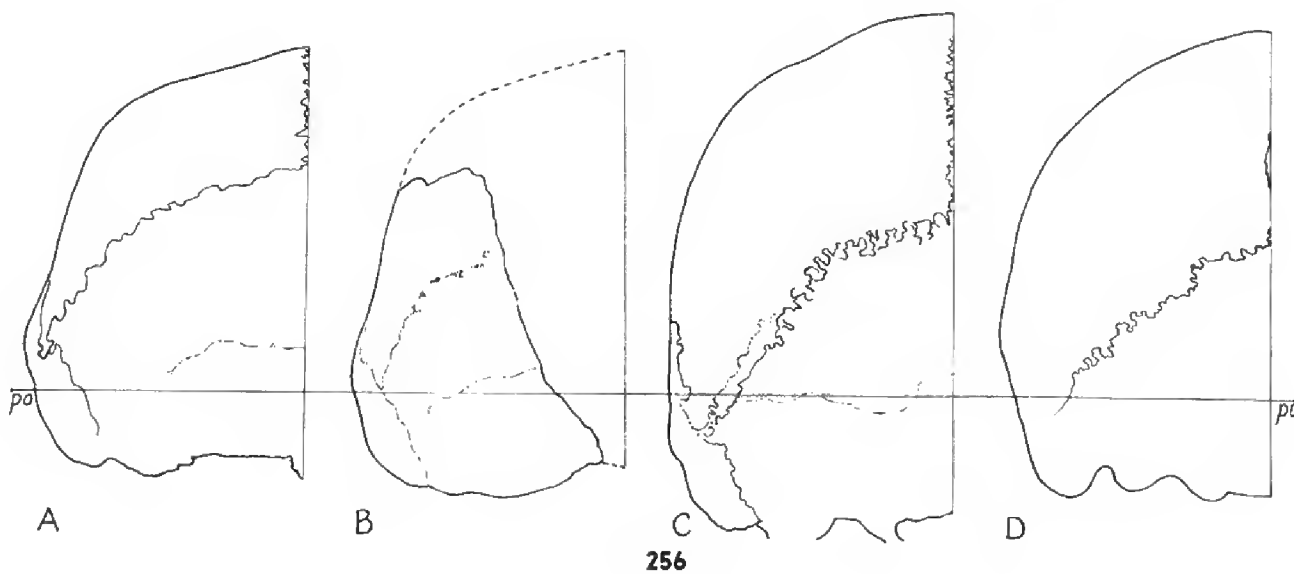
Fig. 254. Mid-sagittal index-diagrams of the various Piltdown reconstructions compared with the index diagram of the average Neanderthal (· · · · · ·) and modern Man (————). All measurements are related to the nasion-opisthion line which equals 100. 2/3. Piltdown reconstructions made by Woodward-Barlow – – –; by Keith (II) ————; by Friederichs –·—·—·— Abbreviations: b, bregma; i, inion; l, lambda; n, nasion; o, opisthion; op, opisthocranion; v, vertex.

Fig. 255. Mid-sagittal index-diagrams of some Neanderthalians compared with those of *Pithecanthropus* Skull II (oooo) and average modern Man (————). All measurements are related to the nasion-opisthion line which equals 100. 2/3. *Homo soloensis* Skulls (average) ————; Steinheim Skull · · · · · ·; Gibraltar Skull –·—·—·—; Rhodesian Skull – – –; Keith's second Piltdown reconstruction ·—·—·; Skhūl Skull V · ·—· · Abbreviations see Figure 254.

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255
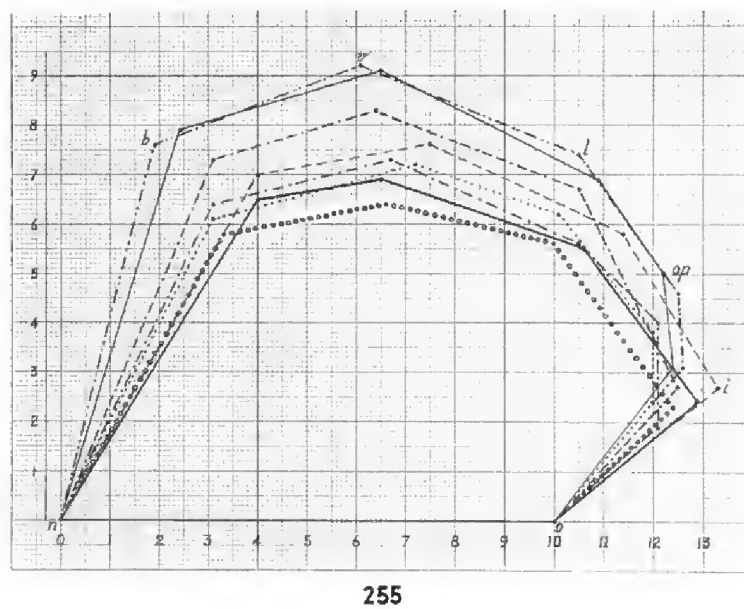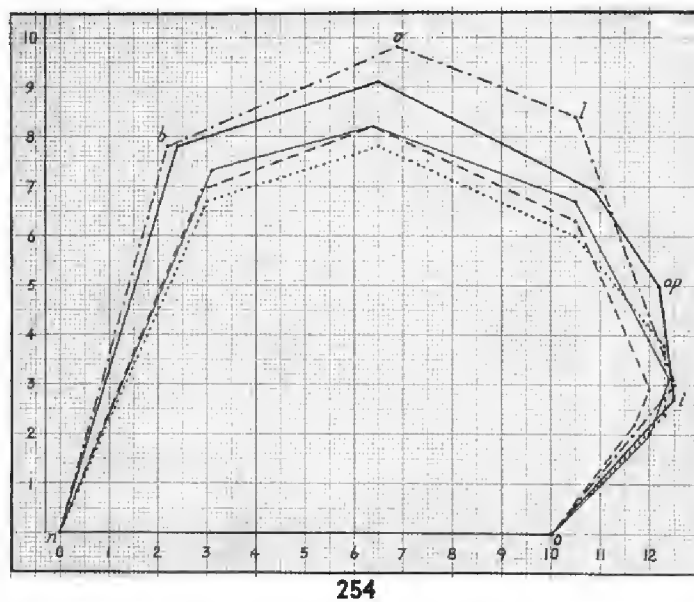
Fɪɢ. 257.   Skiagram of *Pithecanthropus* Skull II.   Coronal and sagittal sutures (bregma).   Photographed with the top of the skull toward the film.   1/1.

Fɪɢ. 258.   Skiagram of *Pithecanthropus* Skull II.   Sagittal and lambdoid sutures (lambda).   Photographed with the top of the skull toward the film.   1/1.

Fɪɢ. 256.   See Plate LXXXIII.
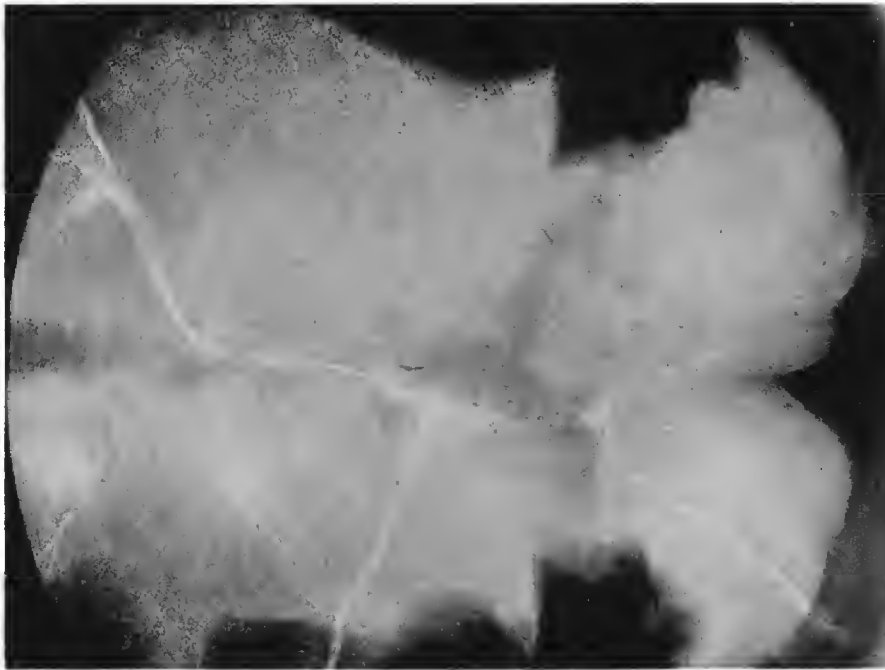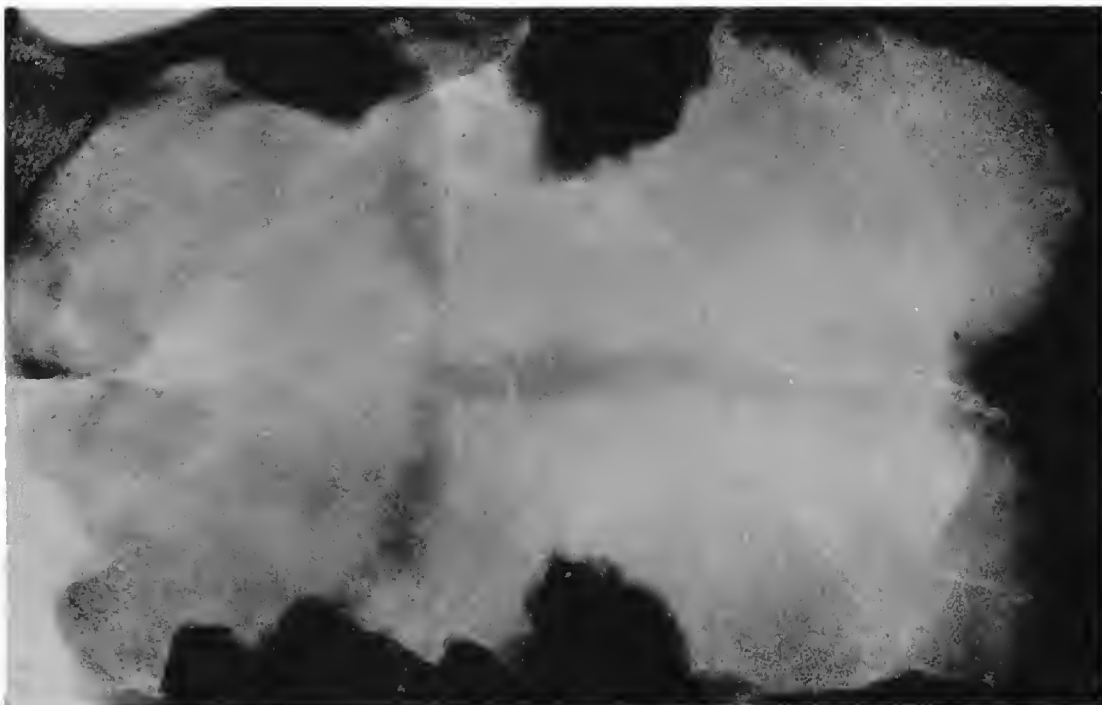
Fig. 259. *Pithecanthropus* Skulls I and II: A, Trinil cap (Skull I); B, Skull II (von Koenigswald). 1/2. A, Norma lateralis sinistra; B, norma lateralis dextra.

Fig. 260. *Pithecanthropus* Skulls I and II: A, Trinil cap (Skull I); B, Skull II (von Koenigswald). 1/2. Norma verticalis.

A 259A

A 259B

B 259A

B 259B

A B 260
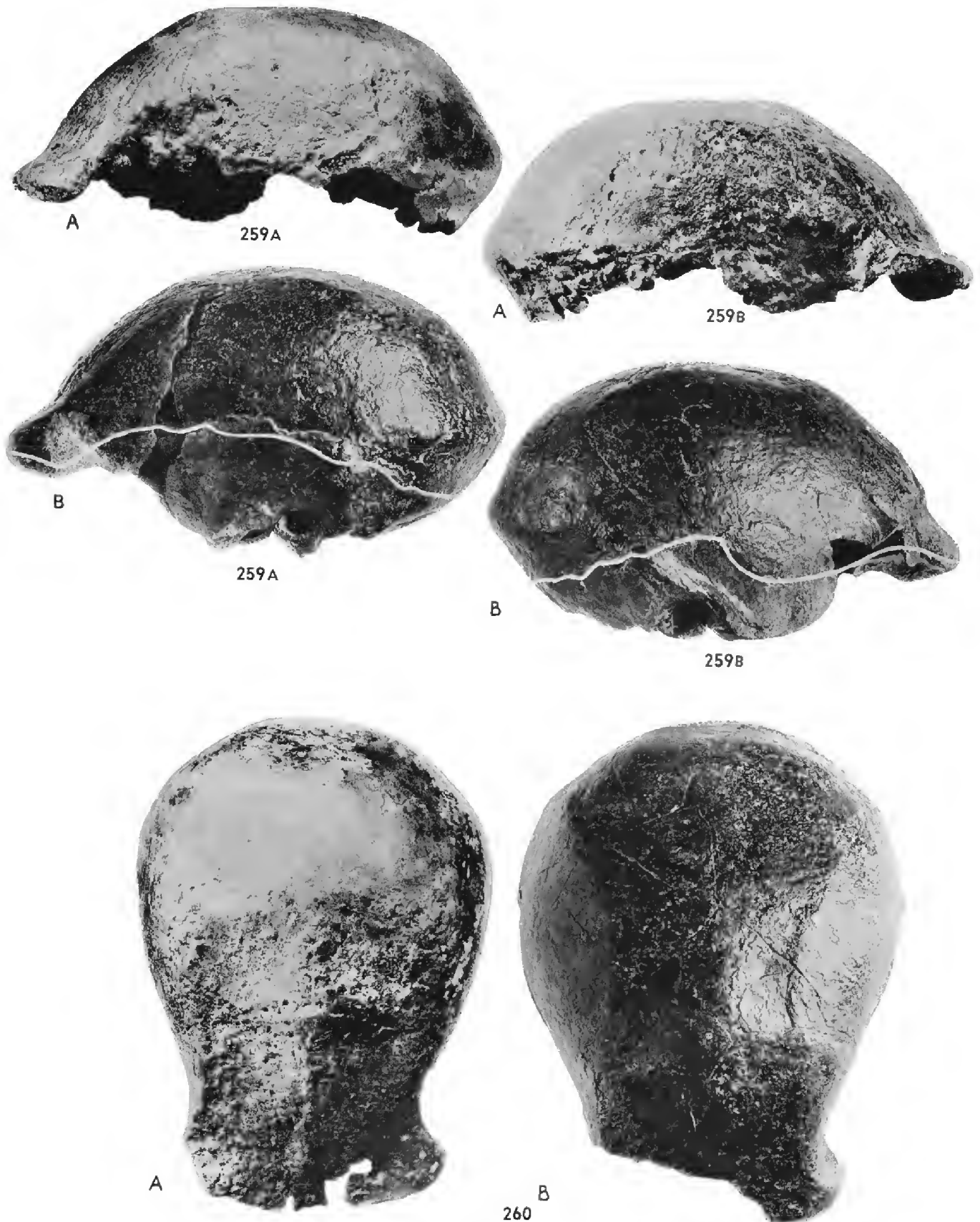
Fig. 261. *Pithecanthropus* Skull III with the matrix adhering to the inside. The parietal bones viewed from in front. See also Figure 247. About 3/4.

Fig. 262. Diagrams indicating the robustness (length × breadth) of the crowns of the upper teeth: C − M³. All measurements in squaremillimeters. 1/2. *Pithecanthropus* Skull IV − −; *Sinanthropus* (maximum values) ——; modern Man (average) ——; gorilla ♀ ······; orang-utang ♀ oooo; chimpanzee ♂ and ♀ ·-−-·.

Fig. 263. Diagram indicating the robustness (length × breadth) of the crowns of the lower teeth: P₂ − M₃. All measurements in squaremillimeters. 1/2. *Pithecanthropus* Mandible B − −; *Sinanthropus* (maximum values) ——; modern Man (average) − − −; gorilla ♀ ···; orang-utang ♂ ooo; orang-utang ♀ oooo; chimpanzee ♂ ·-−-·.

Fig. 264. Normae laterales sinistrae of *Pithecanthropus* Skull II (A); *Homo soloensis* Skull V (B); Australian aborigine ♀ —Coll. Sydney, no. 792, described by Burkitt and Hunter; 1923—(C). A, photograph from the original; B and C, photographs from casts. The three skulls reduced to the same greatest length. About 1/4.

Fig. 265. Upper part of the head of an Australian aborigine. (Note the receding forehead and the deep intraglabellar notch. Photograph after Spencer and Gillen.)

261

A

B

C

264

262   263

265
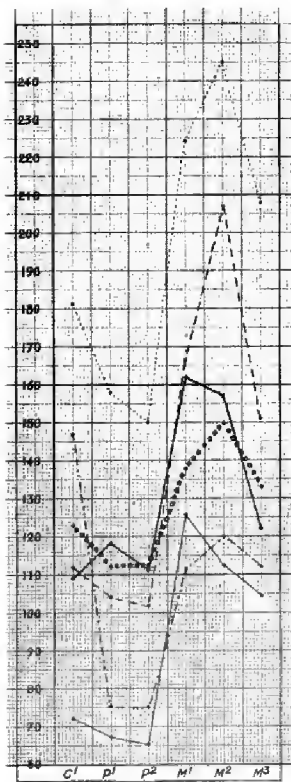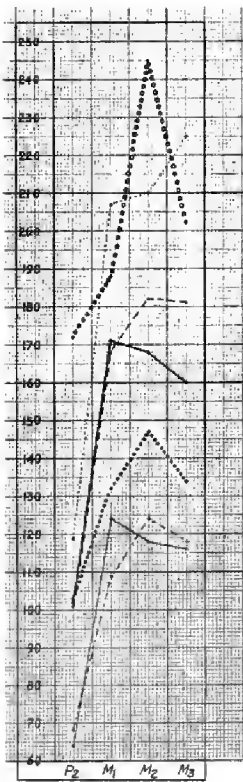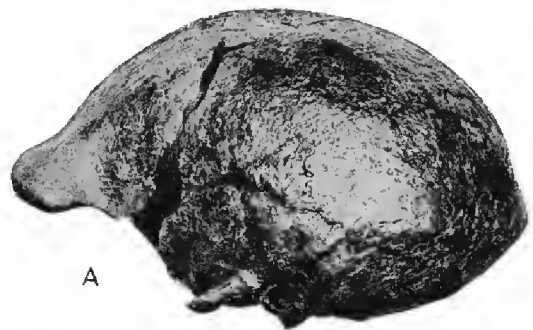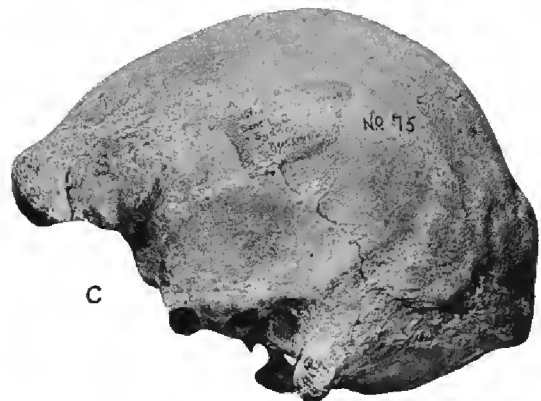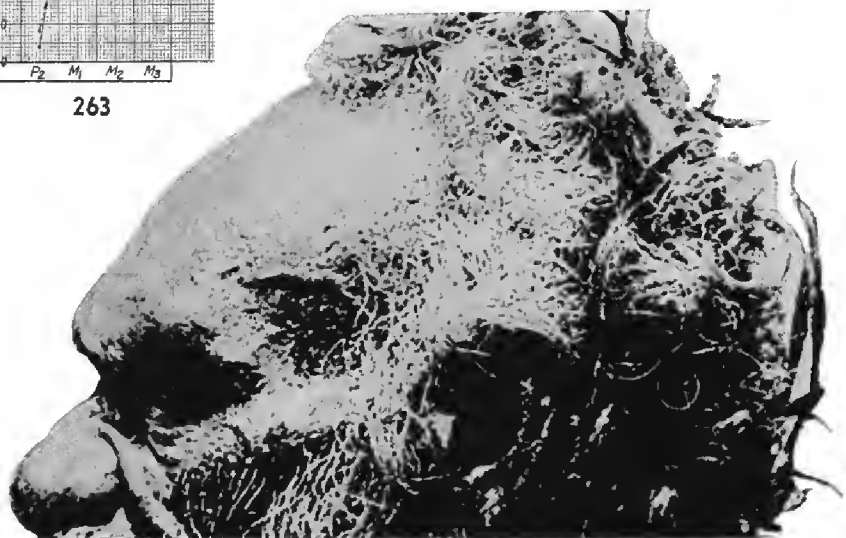
Fɪɢ. 266. Mid-sagittal craniograms showing the differences in height in cases in which the length of the base (nasion-opisthion line) is about the same. *Homo soloensis* Skull I · · · ·; Rhodesian Man – – –; Upper Palaeolitic Man (no. 101) of Choukoutien ooo; Australian aborigine after Burkitt and Hunter ————; Upper Palaeolithic Man of Obercassel –·–·–· 2/3. The craniograms are superimposed from the nasion on the nasion-opisthion line. Areas of basion (ba) and porion (po) marked. Abbreviations: b, bregma; i, inion; l, lambda; n, nasion; o, opisthion; v, vertex.

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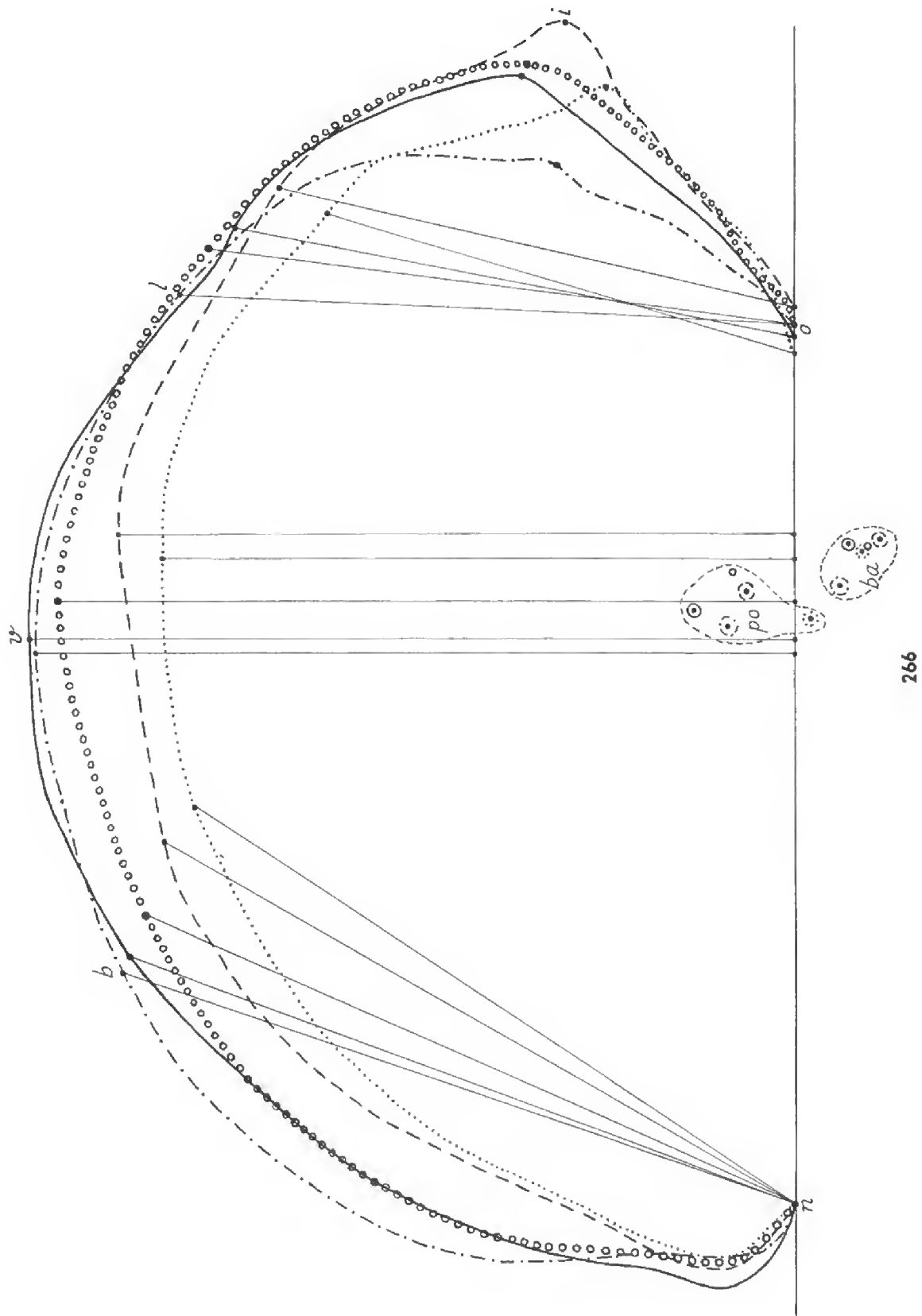
Fig. 267.   Upper Palaeolithic Man (Late Magdalenian) of the "Upper Cave" of Choukoutien: "Old Man" no. 101 (proto-Mongoloid type), A; female skull, no. 102 (Melanesoid type), B; female skull, no. 103 (Eskimoid type) C.   About 1/3.   Norma frontalis.

Fig. 268.   Upper Palaeolithic Man (Late Magdalenian) of the "Upper Cave" of Choukoutien.   About 1/3. The same skulls as in Figure 267.   Norma lateralis sinistra.

A

A

B

B

C
267

C
268
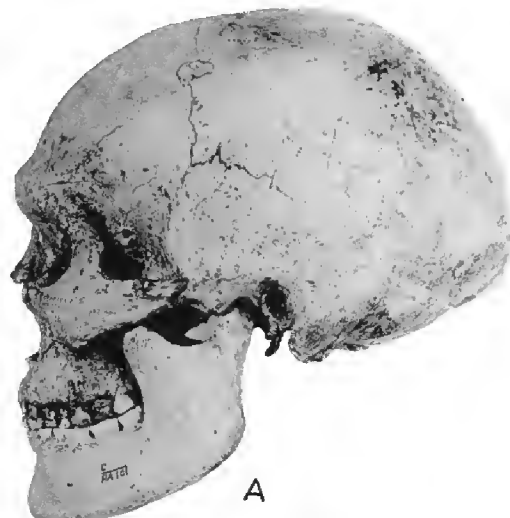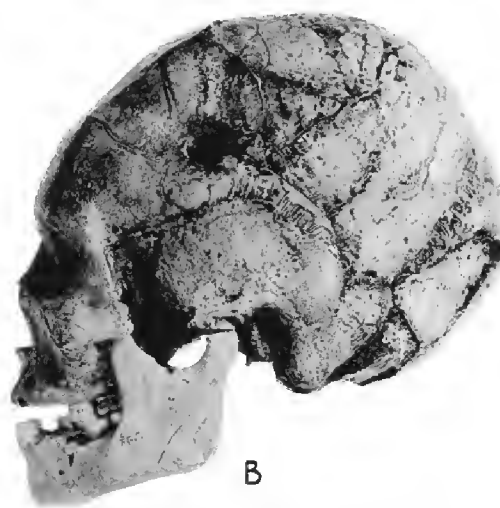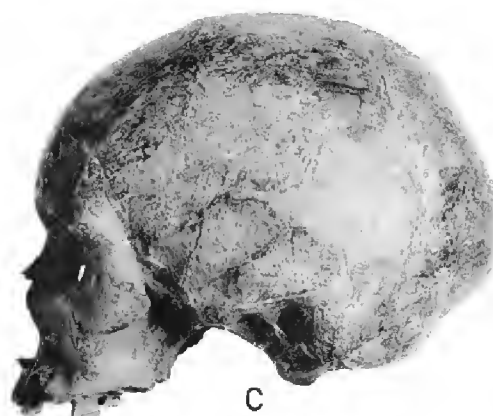
Fɪɢ. 269. Skulls of three canine races differing in size.   The skulls A and B have been reduced to the biauricular breadth of the smallest skull C.   The cranial cavities are shaded.   Norma lateralis sinistra.   A, Irish wolfhound ♂ (A.M.N.H.; no. 90250); 1/4; B, English bulldog ♂ (A.M.N.H.; no. 69453), about 1/3; C, King Charles spaniel (A.M.N.H.; no. 19182); 3/4.   Abbreviations: b, bregma; lt, linea temporalis; n, nasion; nc, nuchal crest; pp, postorbital process; sc, sagittal crest.

Fɪɢ. 270. A, skull of a male gorilla (A.M.N.H.; no. CA 506); B, reconstruction of *Pithecanthropus* Skull IV; C, skull of a male Austrian (A.M.N.H.; no. 3818).   Norma lateralis sinistra.   The cranial cavities are shaded.   1/3.   Abbreviations: b, bregma; n, nasion.
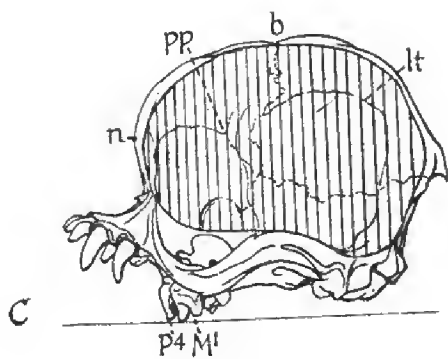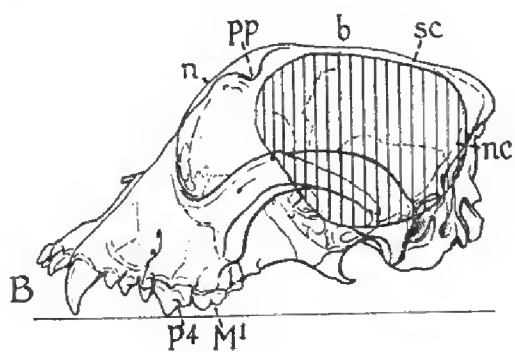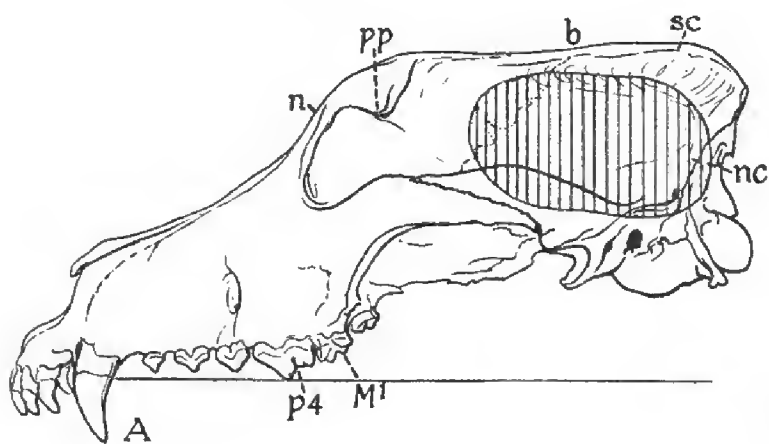
269
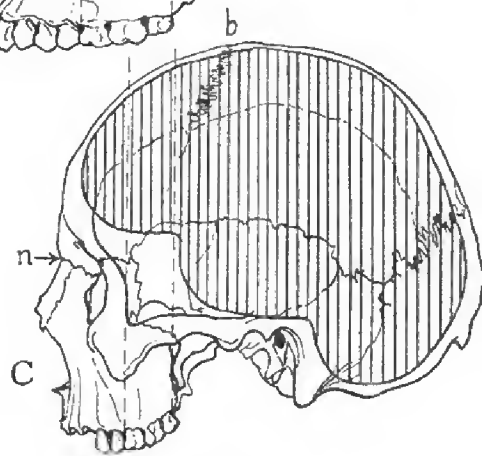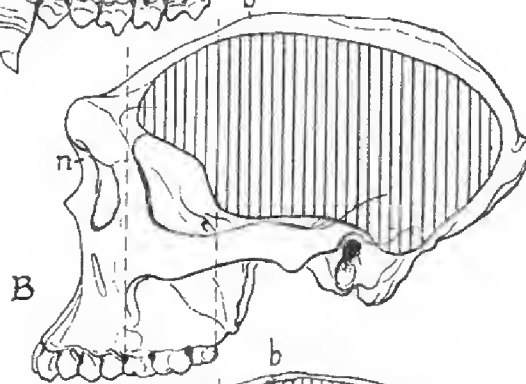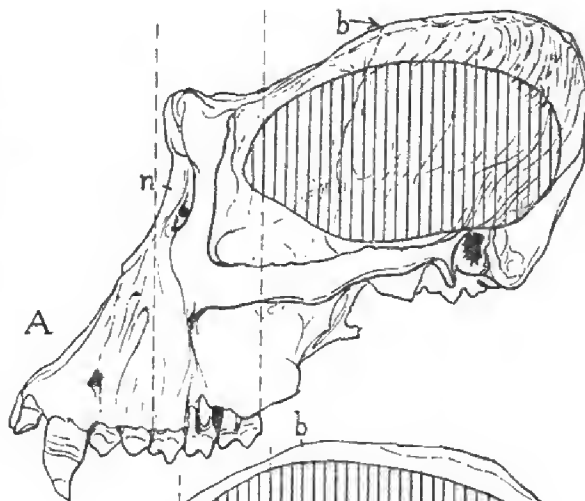
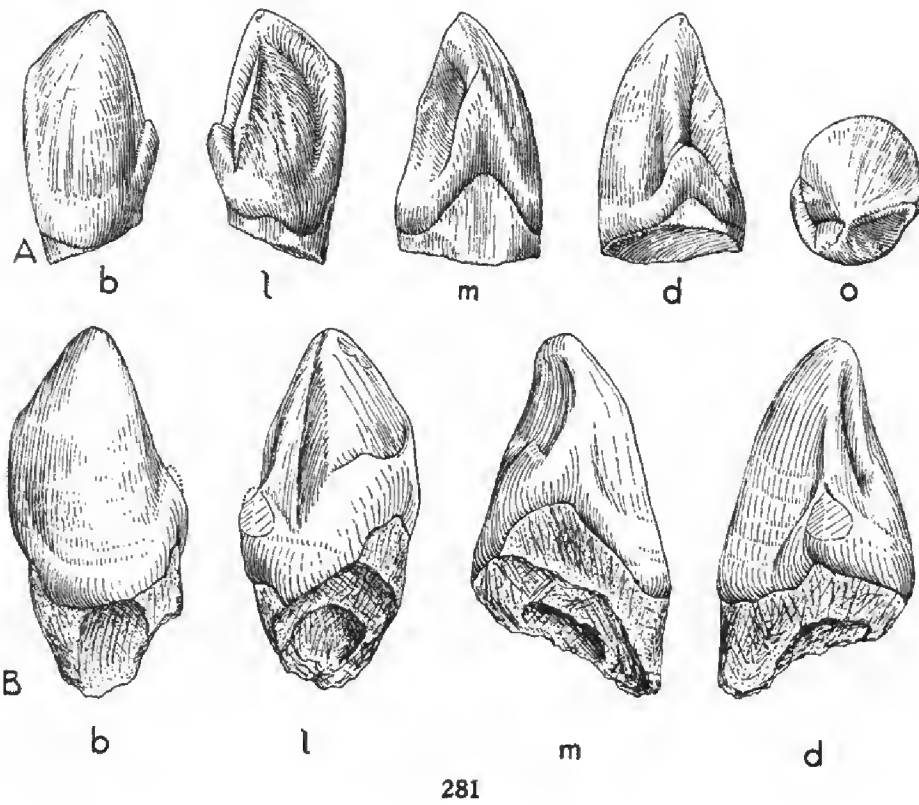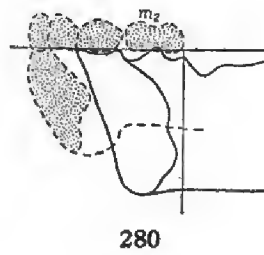270

Fig. 271. The three canine skulls of Figure 269 in norma verticalis. Abbreviations see Figure 269.

Fig. 272. The three anthropoid-hominid skulls of Figure 270 in norma verticalis. Abbreviations see Figure 269.

Fig. 273. Two feline skulls in norma verticalis. A, *Felis bengalis sinensis*, ♂ (A.M.N.H.; no. 60054). 3/4. B, *Felis leo massaica* ♂ (A.M.N.H.; no. 30242) c. 1/5. The lion skull reduced to the total length of the cat skull. The cranial cavities are shaded. Abbreviations: cs, sutura coronalis; lt, linea temporalis; pp, postorbitalis process; sc, crista sagittalis.
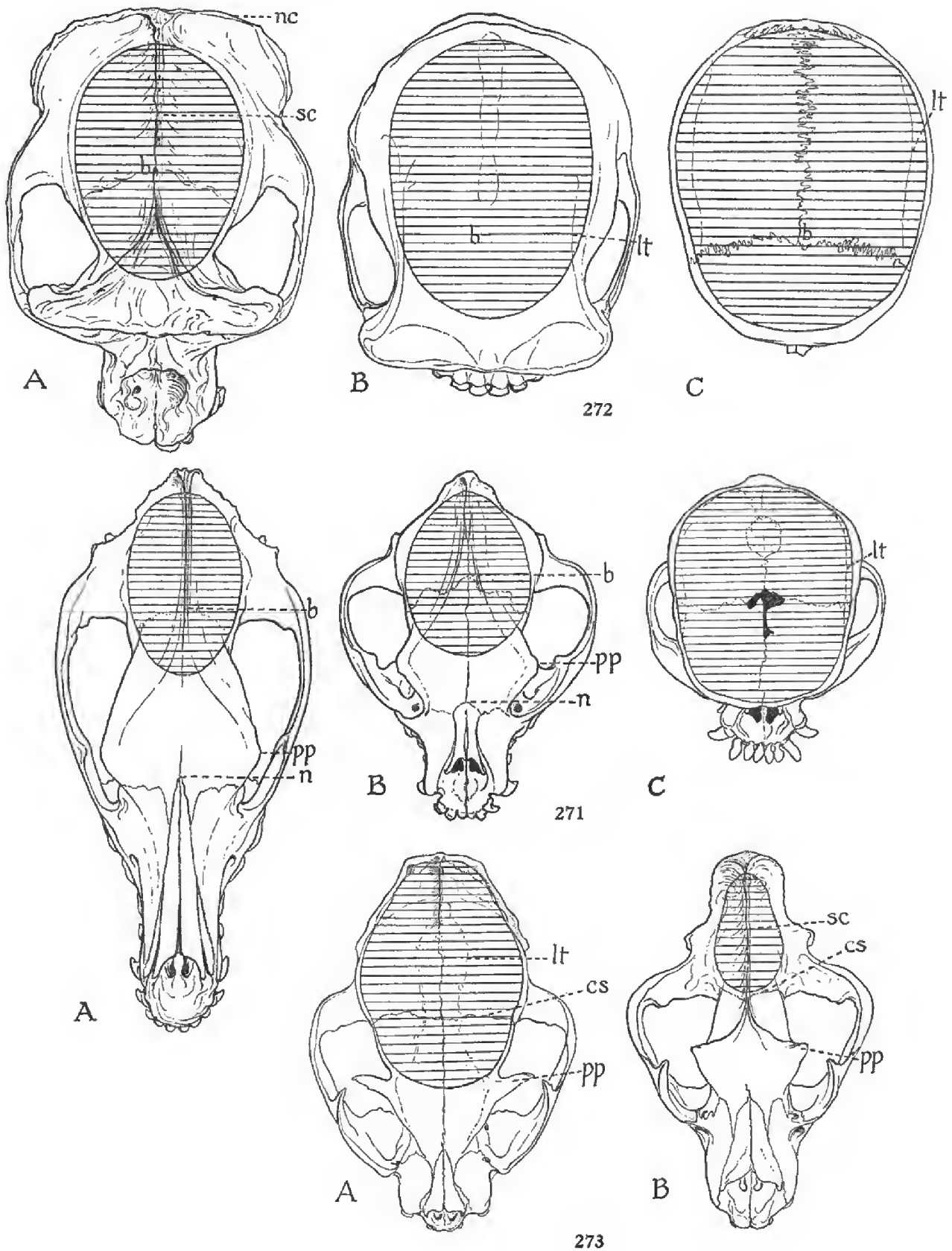
Fig. 274. Upper right (A) and lower left (B) canine of a female *Sinanthropus* individual (Cat. nos. 13 and 70 in Weidenreich; 1937, b). 2/1. Abbreviations: b, buccal; l, lingual; m, mesial; d, distal.

Fig. 275. First lower premolar (right side) of a female *Sinanthropus* individual (Cat. no. 80 in Weidenreich; 1937 b). Abbreviations see in Figure 274; o, occlusal.

Fig. 276. Dental arches of South American Indians: mandible of a female child with completed deciduous dentition (– –) superimposed on that of a female adult (———) on the postlacteal transversal and alveolar horizontal planes. Occlusal view. 1/2.

Fig. 277. The same mandibles as in Figure 276. Lateral view. 1/2.

Fig. 278. Dental arches of orang-utangs: mandible of a male child with completed deciduous dentition (·······) superimposed on that of a male adult (—) on the postlacteal transversal and alveolar horizontal planes. Occlusal view. 1/2.

Fig. 279. The same mandibles as in Figure 278. Lateral view. 1/2.

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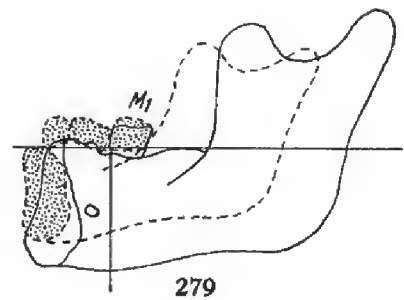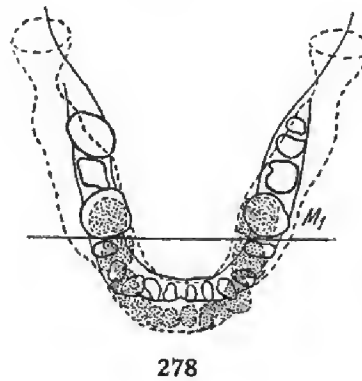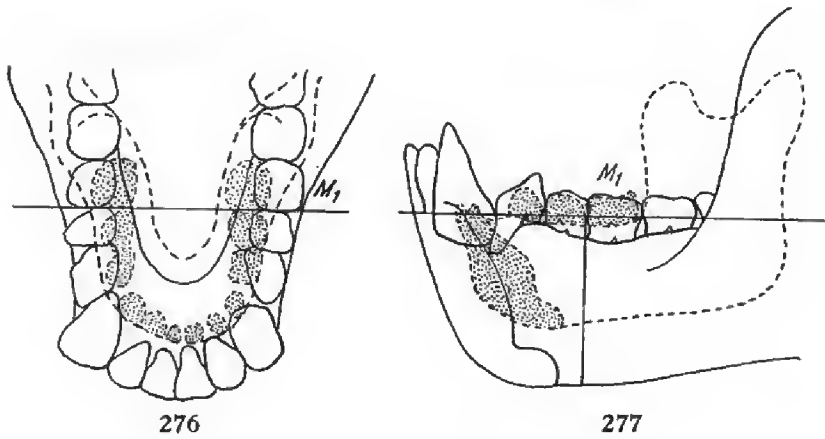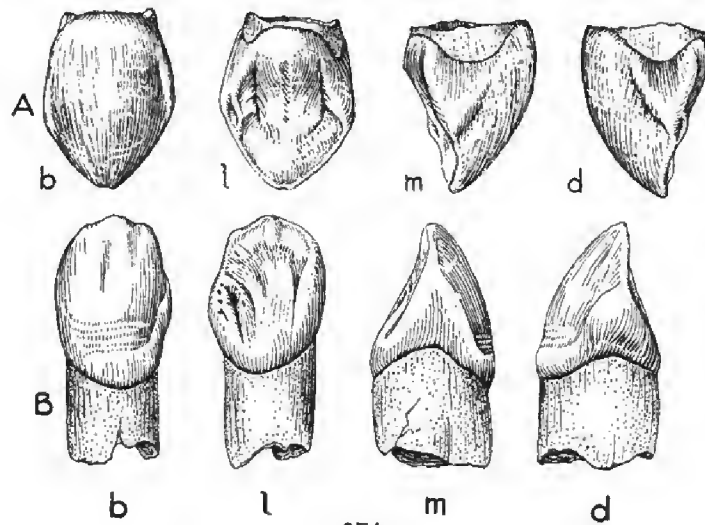
FIG. 280. Dental arches of *Sinanthropus*: Lacteal arch of the mandible of the female *Sinanthropus* child B IV (– –) superimposed on the male *Sinanthropus* Mandible H I (———) on the postlacteal transversal and alveolar horizontal planes. Lateral view. 2/3. m₂, second deciduous molar.

FIG. 281. Lower left canine of *Plesianthropus transvaalensis Broom* (A) and lower right (reversed) canine of a fossil orang-utang—cf. Weidenreich, 1937, b; Pl. VII; Fig. 61—(B). A, drawing from the cast. 2/1. Abbreviations: b, basal; l, lingual; m, mesial; d, distal, o, occlusal.

FIG. 282. Combination of the mesial moiety of the *Sinanthropus* lower canine as illustrated in Figure 274, B, and the distal moiety of the *Plesianthropus* lower canine as illustrated in Figure 281, A. 2/1. *Sinanthropus* moiety reduced to the same size as that of *Plesianthropus*.

中國猿人之頭骨

魏敦瑞著

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中華民國三十二年